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ABBREVIATIONS.—P = Paper; D = Discussion; I = Illustrated.
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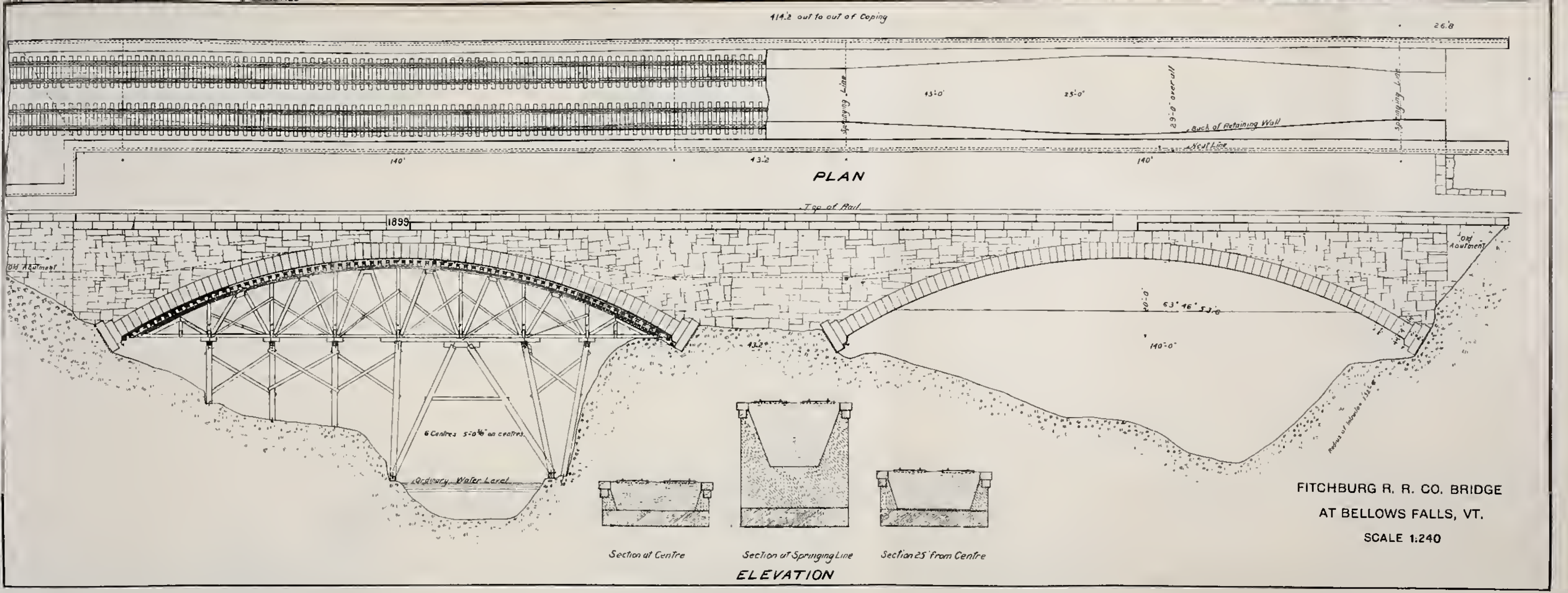

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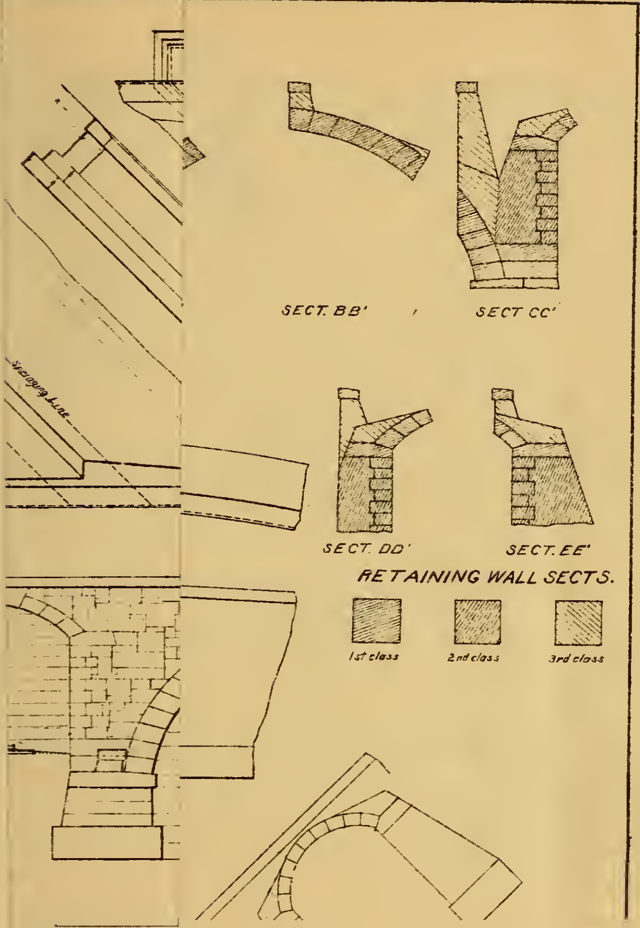

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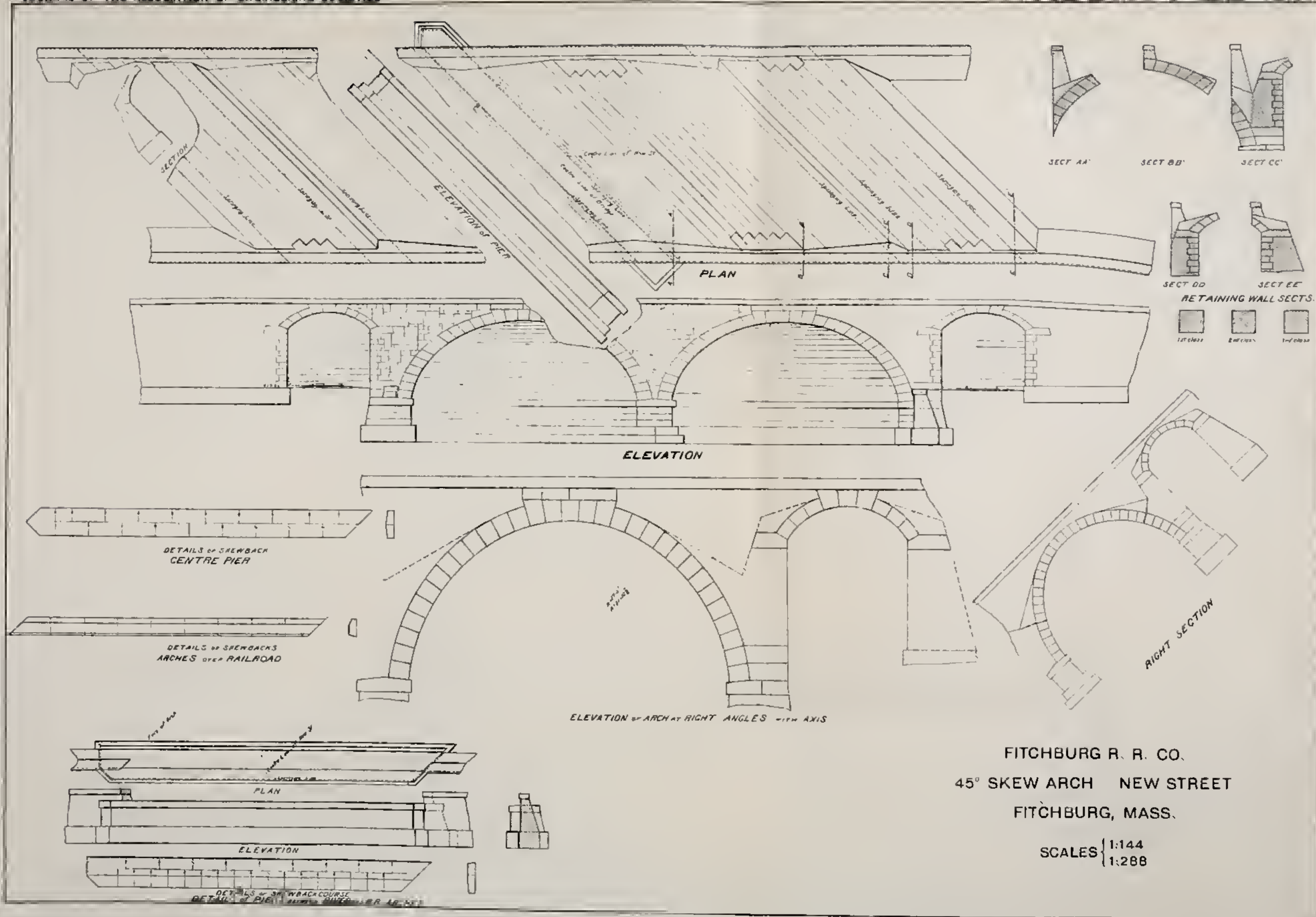
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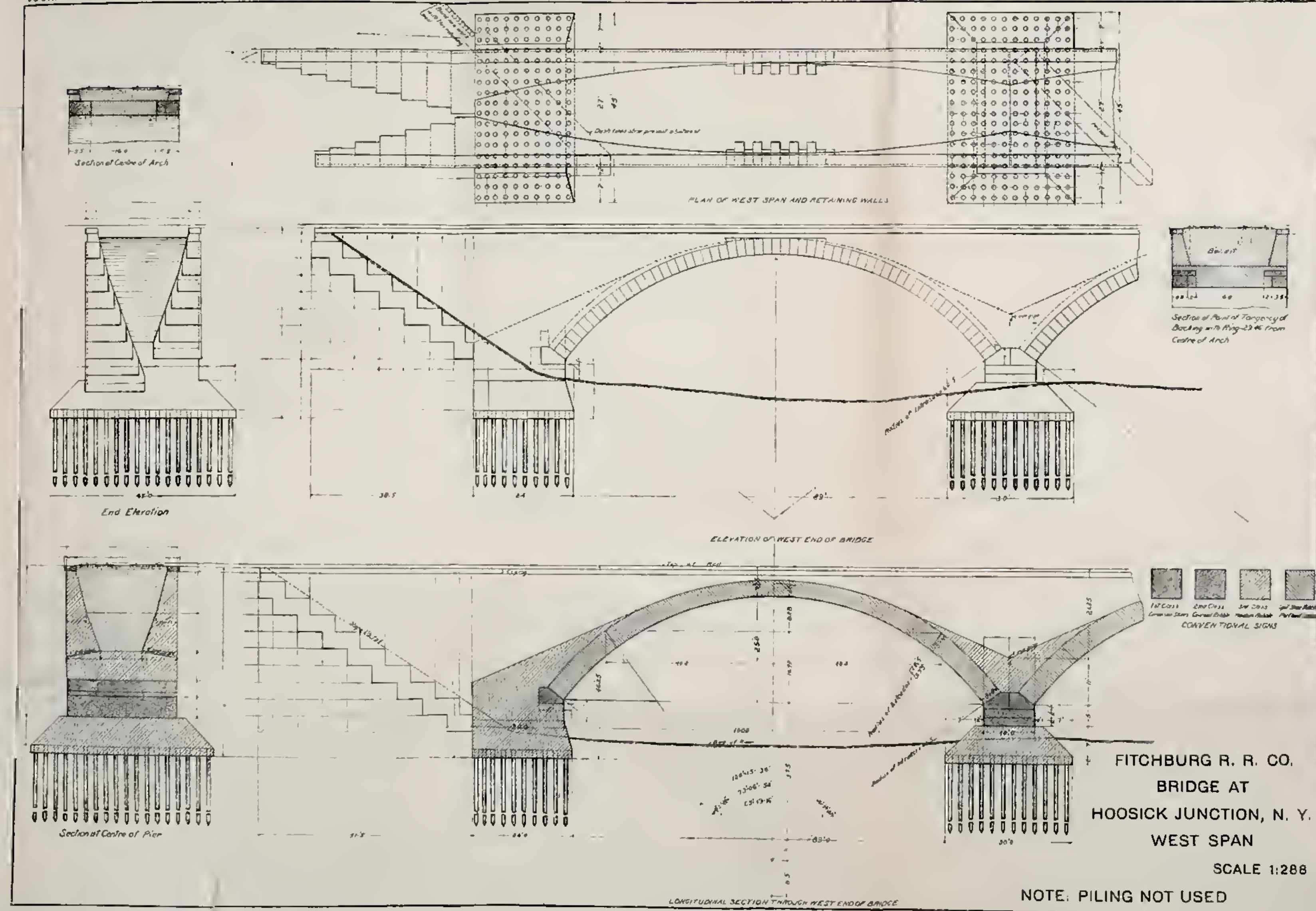
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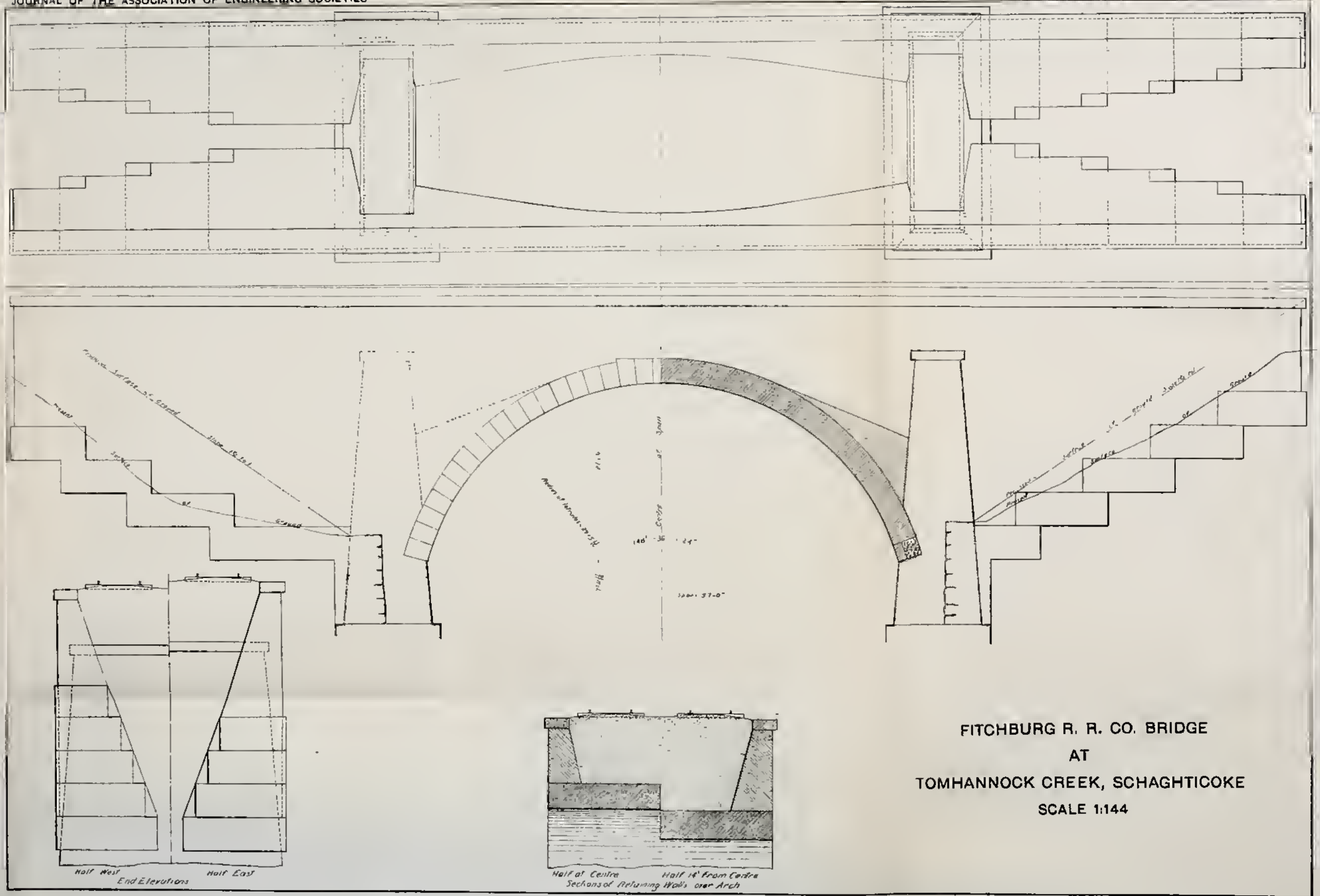

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ASSOCIATION
OF
ENGINEERING SOCIETIES.

Organized 1881.

VOL. XXVII. JULY, 1901. No. 1.

STONE ARCH BRIDGES RECENTLY CONSTRUCTED ON THE FITCHBURG RAILROAD.

BY ALBERT S. CHEEVER, MEMBER BOSTON SOCIETY OF CIVIL ENGINEERS.

[Read before the Society, December 19, 1900.*]

DURING the fifteen months just past, five stone arch bridges have been constructed on the Fitchburg Railroad. The construction of these arches, instead of steel bridges, was primarily due to the high prices of structural steel which prevailed during the year 1899, and to the difficulty of getting quick delivery after orders were placed. The bridges were located as follows:

(*a*) One double track railroad bridge, having two spans of 140 feet each, carrying the Cheshire Branch over the Connecticut River at Bellows Falls, Vt.

(*b*) One highway bridge, having two spans of 38 feet each and two spans of 14 feet each, carrying New Street, in Fitchburg, Mass., over the Nashua River.

(*c*) One highway bridge, having two spans of 40 feet each, carrying Putnam Street, in Fitchburg, Mass., over the Nashua River.

(*d*) One double-track railroad bridge, having two spans of 100 feet each, carrying the tracks of the Fitchburg Railroad over the Hoosick River at Hoosick Junction, N. Y.

(*e*) One double-track railroad bridge, having one span of 58 feet, carrying the tracks of the Fitchburg Railroad over the Tomhannock River near Schaghticoke, N. Y.

The largest and most interesting of these structures is the bridge at Bellows Falls. In the latter part of August, 1899, it be-

*Manuscript received May 27, 1901.—Secretary, Ass'n of Eng. Socs.

came evident that the old wooden bridge which had carried trains ever since the construction of the Cheshire Railroad, was in such condition that immediate renewal was necessary. The old bridge (Fig. 1) was a double-track bridge of the trussed-arch type, the arches consisting of four members of white pine, each 10 x 16 inches in section, the lower chord being hung by rods from the arch when the latter was above the chord, and supported on the arch when the arch was below the lower chord. The old bridge was 38 feet wide over all. For twenty years only one track has been used, it having been thought unsafe to load the middle truss, which was apparently the same as the outside trusses, with trains on both

Fig. 1. Old Bridge at Bellows Falls.

tracks at the same time. At the time named, the price of steel was very high and it was impossible to get delivery of bridges until the middle of winter.

Owing to the impossibility of erecting and maintaining false work in the river at that point during the winter and spring, it was probable that if a steel bridge had been ordered at once, it would not have been safe to begin erection earlier than about the middle of May. It was also found that stone arches for a double-track bridge could be built for a little more than a single-track steel bridge, and for considerably less than a double-track steel bridge would cost, and that there would be time to build the arches before cold weather set in. The water in the river was then very low, and there was not much probability of a material rise unless heavy rains

should occur during the fall. For these reasons it was deemed best to build arches, and contractors were found who were willing and ready to take the risk of starting at once. Work was begun on September 12th, on November 19th trains were running over a trestle built on the arches, and on December 7th the masonry was completed. The site of the bridge, which is almost directly over the falls, is particularly well adapted for arches, as the bed and banks of the river are of solid ledge, and there is a natural pier of rock in the middle of the river, dividing the stream into two channels. The

Fig. 2. New Bridge at Bellows Falls.

westerly channel is much deeper than the other, and in dry weather carries all the water. At low water the larger part of the water in the river is held up by the dam about a quarter of a mile above the site of the bridge, and is carried around through the canal and the mills, and is discharged into the river channel a short distance below the bridge. During all the time of construction only a small amount of water was passing under the bridge, so that it was possible to place all the posts carrying the false work directly on the ledge, the width of the channel to be spanned being only 40 feet. Nature having already supplied the abutments, it was only necessary to bed the skewback stones in Portland concrete enough to fill

up the holes in the rock, and give a smooth and even bearing. The span of the arches was fixed by the natural conditions, and the rise was limited by the old bridge which had to be kept in place for the operation of trains. The arch ring was carried as close as it was possible to lay stone under the bottom chord of the bridge, and, in order to work with all possible rapidity, the outside trusses and one track of the bridge, which was a three-truss double-track bridge, were removed. This left only 12 feet of the width of the arches under the bridge, and made it possible to lay the ring stones without difficulty, except a few at the crown of the arches, which had to be handled by tackle attached to the floor of the bridge. The ring stones are 4 feet thick, 2 feet wide and from 6 to 8 feet long. There are 72 courses in each arch. The stones are cut to a ½-inch joint on the intrados, opening to 2 inches on the extrados. As the stones were laid, V-shaped strips of wood were fitted between the joints on the intrados, to prevent the mortar from dropping out. The joints were then filled with Portland cement mortar, mixed one part of cement to two of sand, and they were thoroughly tamped with strips of 3 x ½-inch iron about 4 feet long, so that every crevice was completely filled. After this was done, as many pinners of stone as could be put in were forced into the joints. The arch first built was turned in six days, the second in four days. Considerable discussion arose as to the probable amount of settlement which would occur, and, to provide for it, the centers were made 3 inches high. Before the rings were closed the weight of the stone settled the centers 1 inch, but after the centers were removed no settlement whatever could be measured in either of the arches. After the arches were turned, it was an easy matter to build the rubble masonry of the side walls, and this was rapidly done. Trains were transferred to a single-track trestle built on the arches and the remaining part of the old bridge was thrown into the river bed and burned. The centers were removed in the latter part of December, so that they were in place only about a month after the second arch was turned. The completed bridge is shown in Fig. 2 and in Plate I. The dimensions and quantities of the work are as follows:

Span of arches	140 feet.
Rise of arches	20 "
Thickness of rings	4 "
Width of arch sheeting	27 "
Width of bridge at track level	29 "
Length of coping over all	414 "
First-class masonry	1,443 cu. yards.
Third-class masonry	2,467 " "
Timber in centers	232 M feet.

At the same time that the Bellows Falls arch was started, the work of abolishing the grade crossings at Water and Putnam Streets at Fitchburg was going on. The plan provided for two steel bridges with plank floors for carrying highways over the Nashua River. As there was a strong desire among the citizens of Fitchburg to have solid floors with granite paving, it was finally arranged to substitute arches for the steel highway bridges. The high price of steel brought the cost of a bridge, heavy enough to carry a floor of I-beams and concrete arches, to about that of a stone arch bridge. The angle of the crossing of New Street (Plate II) and the river is 45°, and if the skew arches had been built, the cost would have been

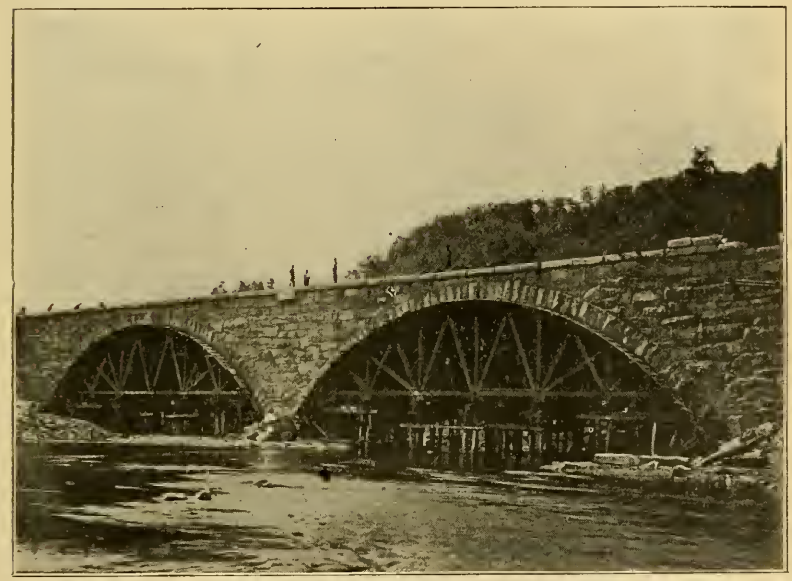

FIG. 3. BRIDGE AT HOOSICK JUNCTION.

prohibitive. It seemed at first rather startling, and opposed to the usual practice, to build skew arches with the joints parallel to their axes, and to cut off the ends on so great an angle, especially as there was only 30 feet of the total length of 70 feet of the abutments squarely opposite. Arches had been built in a similar manner, but no case came to notice where the ends had been cut at so great an angle. Faith in the efficacy of Massachusetts granite and Portland cement finally prevailed, and the arches were built with joints made in the same manner as at Bellows Falls. As this work caused considerable comment among observers, the contractors, as soon as the first river arch was turned, before any of the backing and side walls had

been built and after centers had been drawn, placed a hoisting engine on the keystone at one end of the arch and a derrick on the other end, using them to handle the larger part of the stone laid in the second arch and in the side walls. This was a good object lesson, and thoroughly proved the stability of the arch. When the centers were removed there was no settlement, and no cracks have appeared. The span of these arches is 38 feet, the rise 19 feet. The ring stones are 2½ feet thick.

The bridge carrying Putnam Street over the river was similar to that at New Street, except that the angle of skew was much smaller, only 25°. The span of these is 40 feet, the rise 12½ feet.

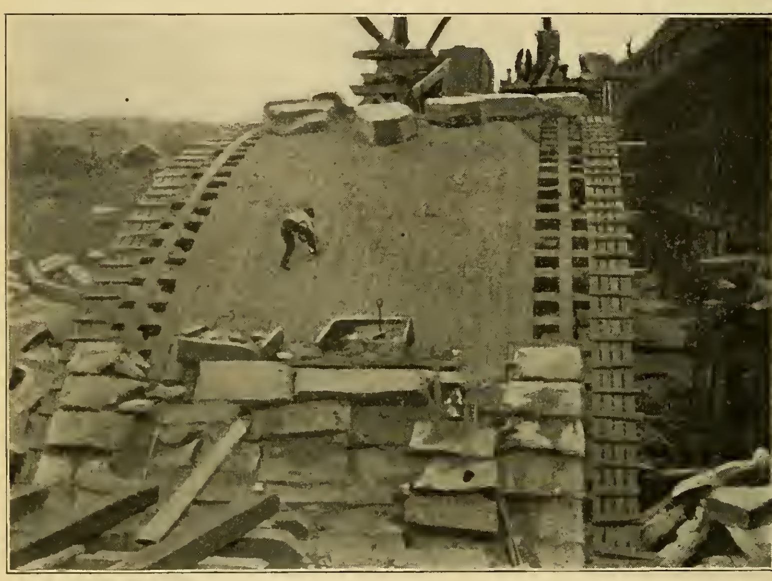

Fig. 4. Centering at Hoosick Junction.

The arch bridge built at Hoosick Junction (Fig. 3 and Plate III) was constructed to replace a two-span iron bridge which was too light for the increased weight of the engines now in use. In order to bring the cost of a masonry bridge down to the cost of a new steel bridge, it was necessary to build the cheapest kind of work that would be sufficient. Cut ring stones could not be used, on account of the expense, and such good success had resulted from the use of open joints tamped full of Portland cement mortar that it seemed perfectly safe and proper to build a rubble arch in the same way, using large sheet stones just as they were taken from the quarry. The railroad company is fortunate in having, on its line, a

quarry in which the seams are regular and parallel, and so even that the natural beds of the stones are almost good enough for ashlar work without any cutting. All the stone used in the bridge was from this quarry. The end ring stones alone were cut, all the rest of the arch sheeting being made of rough stone. The centers were covered tightly with plank (Fig. 4) and the sheeting was set on the centers as closely as possible, all openings being thoroughly filled and tamped with Portland cement mortar, in the same way as was done at Bellows Falls. The result, after removing the centers, was even better than was expected, no settlement occurring and not a single crack appearing in any of the masonry. The foundations for

Fig. 5. Bridge over Tomhannock River at Schaghticoke.

this structure deserve some mention. Samples of material from borings, to a depth of 30 feet below the bed of the river, indicated that piles should be driven, but this question ot pile foundations was most thoroughly settled when the temporary pile bents were driven, to carry the iron bridge, which was moved to one side to carry trains around the work. The driving of these piles showed the difficulty of penetrating the bed of the river, and that the borings did not give a proper idea of the material. This was still further proved by the time one of the foundation pits was excavated to the point where the masonry was to start. The bottom was of hard compacted gravel, and it became evident that piles were unnecessary and they were omitted. The iron bridge was moved to

one side to allow room to construct the arches. The bridge was on a 45° skew, and consisted of three quadruple lattice trusses continuous over the pier, placed 9 feet apart center to center. The bridge was 250 feet long, about 16 feet deep, and, with the track ties, which were not removed, weighed about 225 tons. Previous to moving the bridge and without any disturbance of traffic, it was jacked up enough to remove the bed plates on rollers, so as to pass rails under the ends on the centers. Three lines of heavy pile trestle were built, extending from the masonry to the new position of the bridge, each of them being capped with 14 x 14-inch hard pine timbers carrying three lines of rails. Hitches were made to timbers buried in the ground, and to the ledge on the other side of the river opposite the ends and the center, and lines were carried from the bridge through two sets of double blocks back to three hoisting engines. The first pull moved the bridge about 5 feet, and, as the lines were so arranged that no overhauling of the falls was necessary, the bridge could have been moved over in ten minutes had it not been for the trouble caused by rivet heads in the bottom chord binding against the nuts in the joints of the rails. It was not possible for the hoisting engines to pull equally, and the bridge could be moved only a few feet at a time. It was then stopped by one end getting a little ahead of the other, and this caused the rivet heads to bind against the bolts of the rail joints. Considerable time was used up in finding and cutting out the rivets which were holding the bridge. This was, of course, greatly increased by the large angle of skew; but, notwithstanding the trouble caused by the rivet heads, the bridge was in its new position in one hour and twenty minutes after the first pull was made.

The arch over the Tomhannock River at Schaghticoke (Fig. 5 and Plate IV) was built under the middle span of a three-span plate girder bridge and the other two spans were filled up, after removing the old iron bridge. This arch was built in the same way as that at Hoosick Junction, and was comparatively a small affair, the interesting point about it being that it enabled a bridge 200 feet long to be removed and a solid roadbed to be carried over the river, and that it cost no more than it would have cost to renew the superstructure of the bridge with new plate girders for double track.

ARCH CENTERS.

By James W. Rollins, Jr., Member Boston Society of Civil Engineers.

[Read before the Society, December 19, 1900.*]

A properly designed arch center must have three vital qualities: strength to carry the weight of the arch before the key is placed; stiffness in its members to prevent distortion under a partial load, and a foundation to start on. With these conditions satisfied, any arch should be laid and should be closed without trouble.

In columns and beams the question of mere strength is easily solved. That of stiffness is much more difficult. Necessarily,

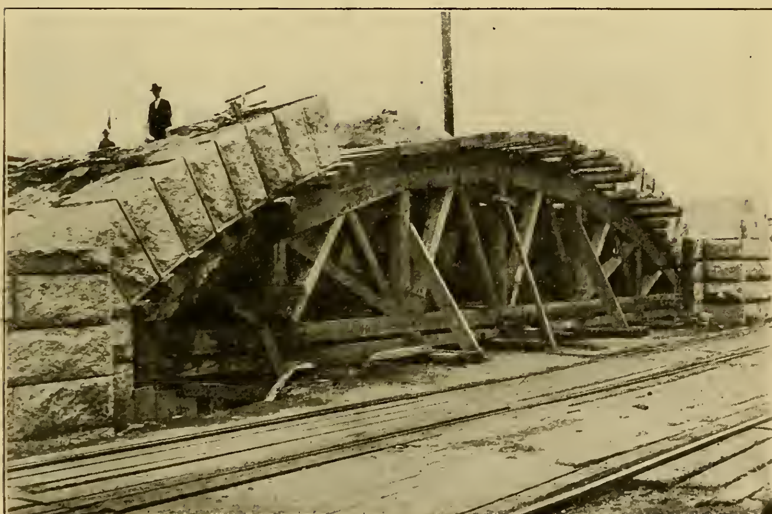

Fig. 1. Centering for a Flat Arch.

centers are often trussed in some way, and absolute rigidity in a truss cannot be secured in practice.

As for foundations, there is always difficulty in getting such as are able to carry a heavy load without any settlement whatever.

The .trouble of settlement from weakness of foundations, or from lack of rigidity in frames, begins when the sheeting extends about 20° from the skewback; for, except in very flat arches, most of the weight of the first few courses is carried by the skewback, and very little by the centers, so that after some weight comes onto the centers, their joints are compressed, and this opens some of the joints in the masonry already laid. If the foundations are firm, this

*Manuscript received May 27, 1901.—Secretary, Ass'n of Eng. Socs.

cracking may be avoided, in part, by using counter-bracing at the first and second "panel points" of ribs.

For small arches the simplest center is a circular rib made of three pieces of 2-inch plank, laid with broken joints, all being spiked solidly together, with a tie of plank at the springing. On this, 1-inch lagging is laid close. For a larger arch, the circular rib, as above described, with generally three braces, one at center and one on the quarter at each side, is used, the center of the whole rib having a post under it. We have used such a center up to 30-foot span for both brick and granite arches, carrying a 30-inch arch sheeting.

The design of a center for larger arches depends upon local conditions, also upon the relation of rise to span. In flat arches,

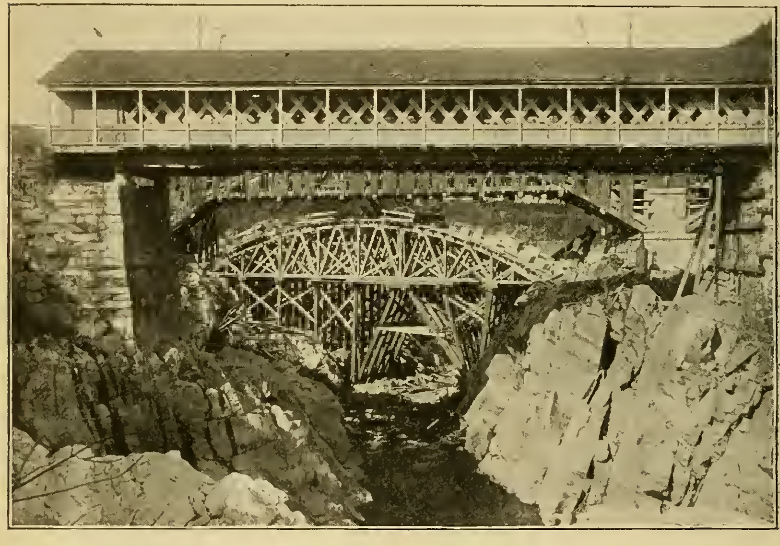

Fig. 2. Centering at Bellows Falls.

Fig. 1, with low side walls, it is well to use posts with intermediate bracing, on numerous supports. In a high arch we may use long braces extending directly from a center support to the rib, at intervals of 6 feet to 8 feet.

In the construction of the large arches for the Fitchburg Railroad over the Connecticut River at Bellows Falls, over the Hoosick River at Hoosick Junction, and over the Tomhannock Creek at Schaghticoke, as described in Mr. Cheever's paper, a departure from the usual method of building the rib itself was made with excellent results.

In the Bellows Falls arch the weight on each post was about 20 tons, and to carry this weight on two pieces of timber bolted to

the end of the post tenoned down to receive them, like a "girder cap" in a railroad trestle, seemed to be poor construction, unless excessively heavy timber was used, and unless most careful jointing was done to distribute the weight evenly over the whole of the bearing surfaces. The method of building ribs for this center, 140 feet span, 20 feet rise, was as follows: A platform was built in an open space, 25 x 80 feet, the half-span of the arch; on this platform the rib was laid out to full size, and templates were made of each post and brace. Then all the timbers, for the twelve ribs making the centers for both arches, were framed from these templates. (Figs. 2 and 3.)

FIG. 3. CENTERING AT BELLOWS FALLS.

The foundations for posts of bents supporting the ribs were cut out of the solid rock, and doweled to it, no sills being used except in the bents on each side of the river. All timber in bents was 14 x 16 inches yellow pine, second-hand material.

These bents, of six posts each, with cap, had short corbels at top of cap under each rib, and on these corbels was placed the lower chord of ribs, 10 x 12 inches spruce, simply butted together. The posts and braces were then put in and stay-braced.

The top chord of the rib was made of four thicknesses of 3-inch plank, laid with broken joints and spiked to posts and braces. The latter were sawed off square or beveled, according to their position, and thus required no mortises, tenons or bolting

in the centers. The posts and braces were then thoroughly X-braced.

The lagging was 8 x 8 inches spruce, 2 feet on centers and under the lagging, at each intersection with rib, a pair of oak wedges 4 inches wide were placed. The arch sheeting was thus placed on 420 pairs of wedges, there being six ribs under the arch, 5 feet on centers. The arch sheeting was 27 feet wide over all. (Fig. 4.)

To hold lagging in position and give the workmen a fair place to work on, 2-inch planks were spiked to the lagging about 2 feet

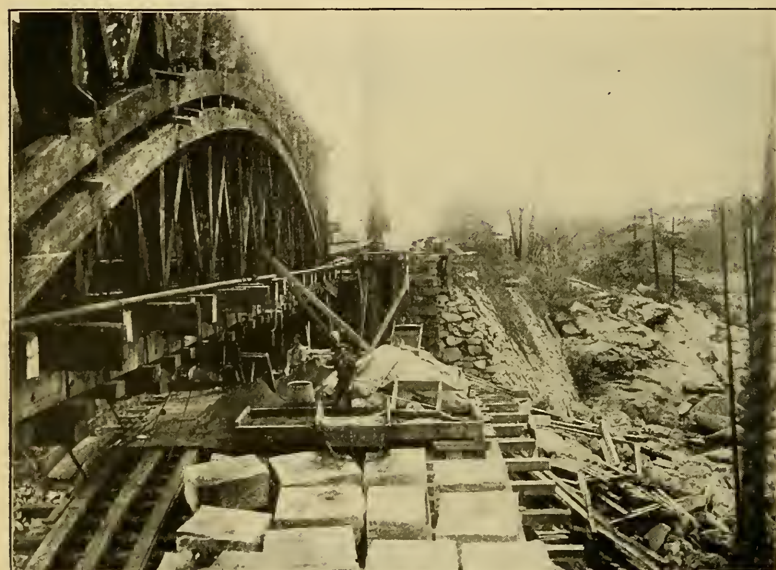

Fig. 4. Laying Arch Stones at Bellows Falls.

center to center, and on this the "sheeting" was laid. As the intrados of the arch was rock-faced, an allowance was made for 3-inch projection, the sheeting being kept to line by wedges on top of the plank. This center proved to be most satisfactory, with the exception of the wedges, and settled only 1 inch under a load of 1500 tons. When the centers were ready to be struck, the wedges "stuck" and refused to budge, except under the most severe mauling, it being necessary in many cases to actually cut them out.

The centers for arches at Hoosick Junction, (Fig. 5) two 100-feet spans, were of similar construction to those at Bellows Falls, the former, however, having a pile foundation. The bottom of the river was a hardpan and into this the piles were driven to a

"refusal." A perfectly solid foundation was thus obtained. Here the rib was of 2-inch plank, six thicknesses, on account of smaller radius of arch, and short corbels were put between the ends of the posts and the top chord of the rib, to stiffen the latter. The method of wedging for this arch proved the best we have ever used, so that, when centers were struck, they came out without any trouble. In this case the wedges were of seasoned oak 8 inches wide, 4 inches thick at thick end, 2 inches at thin end, and 18 inches long. They were *planed* on sliding faces, and were then thoroughly greased. When put in place they were "tacked" together to prevent their

FIG. 5. CENTERING AT HOOSICK JUNCTION.

slipping, and were put in between the caps on the bents and the corbels under the lower chord of rib.

At Schaghticoke an arch of 58 feet span was built (Fig. 6), over the Tomhannock River, between two piers which carried an iron bridge. This arch was almost semicircular, and was over a very shallow river with a solid rock bottom. The center for this was built with a 2-inch plank rib, stiffened by 8-inch timbers between five braces of 6 x 8-inch spruce timbers. All the braces came together on a central support, and, while the structure looked exceedingly light, it stood the test of wear without any sign of failure. The braces were, however, most thoroughly X-braced. The wedges were under the central support and were easily driven out, they having been planed and greased as at Hoosick Junction.

The last arch built—that at Medford, across the Mystic River, of about 60 feet span—presented a problem as to the method of centering. The springing line of arch being 6 or 8 feet under high tide, it was necessary to construct a cofferdam for that part of the arch below the highest watermark, it being deemed impracticable to try to lay the sheeting by "tide work." Piles were driven for the cofferdam at each side, about ten feet inside the springing lines of arch, and on this and a center line of piling, the ribs of centers were built—with extensions down to the skewbacks. To avoid driving too many piles in the river, a trussed center was designed, and stood

Fig. 6. Bridge and Center, Schaghticoke.

up well, under a 30-inch sheeting on a very flat arch. No wedges were used in this center, they being struck by knocking out a line of blocking at the central support.

The question is often raised, How soon can centers be drawn after the arch has been closed? In the opinion of the writer, they should not be drawn until the cement has set enough to stand the pressure, and in pursuance of this practice centers have been struck in three days on a 30-foot arch, in five days on a 60-foot arch and in four weeks on the Bellows Falls arch, with no signs of cracks in any case. If there is no necessity for drawing centers, time will surely add to the certainty of stability of the structure, and no

trouble will ensue if the foundations are equal to the load placed upon them.

For centering for a large arch, or one where the distance from the foundation to top of arch is more than 40 feet—in our opinion the best practice is to use the longest posts available; X-brace them thoroughly; avoid all trussing, as far as possible, and make as few vertical joints as possible.

NOTES ON THE INDUSTRIES OF THE UPPER RHINE.

By John Richards, Member Technical Society of the Pacific Coast.

[Read before the Society, June 7, 1901.*]

I had recently to visit briefly on business the upper Rhine country, especially the Swiss portion, and found time to make some notes relating to technical and industrial matters there that I venture to present before the Society this evening. I am influenced to do so because of various things that were novel and of much interest to myself; no doubt in some cases well known to some of the members present, but not to all. I therefore beg indulgence in respect to what is not novel; also in respect to the broken and discursive nature of these notes, which were jotted down en route and had been worked out by the stenographer here before I arrived at home.

A portion of my journey was made on the River Rhine, and my notes will begin with that, remarking first that the changes of more than twenty years since I had last visited this country have made all things new. Old "Cologne," with 120,000 people then, is now "Köln," with 350,000. Nearly all the Rhine cities have doubled, and many other things have changed accordingly.

The scenic portion of the Rhine, from Bingen to Bonn, has been the subject of more descriptive writing perhaps than any other part of Europe, due more, however, to historic association than to its natural features. The traveler's portion of the Rhine, or that usually traversed by passenger steamers in the summer season, is from Cologne, or Köln, to Mannheim, a distance of about 150 miles, requiring usually twenty hours of time. Throughout that portion of the river that lies between Bingen and Bonn, the Rhine flows between hills 500 to 1000 feet high, rising abruptly from the water's edge, and on all southern exposure the whole attainable surface is terraced and cultivated in vines in a manner that has no parallel in the cost and completeness of the work.

I will venture to say something of this vine or wine culture, and to express some views that I fear will be at variance with commonly accepted opinions.

In the first place, I do not believe that there is much more in this Rhine wine country, in so far as physical features are concerned, than the warmth of the soil from underlying stone cliffs and in a wonderful cultivation, and that, while the climate is harsh

*Manuscript received June 13, 1901.—Secretary, Ass'n of Eng. Socs.

and cold for at least half of the year, this warmth and deep cultivation preserves a genial temperature up to a short distance below the surface.

This feature of warmth, so far as I have noticed it, seems to be peculiar to limestone regions. In Ohio, Kentucky and other Middle States having both lime and freestone bedrock, land resting on the former is several weeks earlier in its vegetation, and the snow melts much sooner in the limestone regions. I do not know whether the Rhine cliffs are limestone, but suspect they are.

Other features are exposure to the sun's hot rays in summer, not attainable on flat lands; also perfect drainage and a freedom from saturation not possible on level lands in any country; but most of all is the intense cultivation and care, of which we know nothing here in California and will not for at least half a century to come.

The depth to which the soil is prepared and the careful manner of it, not to mention the expensive means of retaining the earth, would, to use a slang phrase, "paralyze" a California grower of vines. For a depth of two to three feet, and in some cases much more, the earth is stirred, pulverized, mixed with loam, vegetable mold and manure. It is carefully and endlessly cultivated, indeed, so long as the earth is accessible beneath the spreading vines. The result is an intense growing power, so to speak, carefully modified to the conditions required by the vines.

As to local influences and environment, and in all except the skillful treatment of the vines, there is, in my opinion, nothing in the Rhine Valley that has not a parallel here a thousand times repeated on the mountain sides in California. I also believe that in the Middle States, Ohio, Kentucky, Tennessee and Georgia, for example, the cultivation seen on the Rhine might have a like result.

The great reputation of the wines of the Rhine is at this day to a great extent based on commercial incentives. The trade is immense, and the quality of the wine is unquestionable; but that its merits are due to local conditions of a geographical or climatic nature I much doubt.

It amazes one to think of the possibilities of wine culture here in California. The northern counties could alone sustain a population of many millions of people devoted to this pursuit if a market for the product could be found. Lake County, lying within one hundred miles of this city, has more area for vines than the Rhine Valley from Bingen to Köln, situated at levels up to 3000 feet high, where the best grapes are now grown, down to the lake level or below that, a range of 2000 feet. Nearly the whole of Lake County

could be cultivated in vines under conditions much more favorable than in the Rhine Valley, except as to means of transportation.

The Main, Lahn, Mosel, Nohe, Nette, Wied and other streams enter and swell the Rhine in this hill district; otherwise the volume of water would be insufficient for navigation through the many rapids and obstructions that exist in this portion of the river,— the classic part, it may be called.

In this country we are apt to suppose that the Rhine, after reaching the broken district above Cologne, continues between hills and mountains that grow higher and more abrupt until it enters Switzerland. This is not the case. Above Bingen, and after passing the main wine district, the country again spreads out on each side of the river into wide plains. Basel, Baden, Müllhauser and even Zürich are not in mountains, but in plains, nearly the same as those that begin below Cologne and extend one hundred and fifty or more miles to the delta at Rotterdam.

Throughout its navigable length, the river is not a natural, but an artificial stream; a canal indeed, because dredged out, embanked, straightened and otherwise trimmed up in a manner unknown to any stream on this continent. How such a thing can be made profitable will appear when I come to speak of the traffic.

The number of steam dredges at work on the Rhine in the district from Mannheim to Cologne, or for one-third of the navigable length of the river, is not less than fifty, all of them of an efficient kind and uniform except as to size, which varies a good deal. They are constructed of iron or steel, of the chain-bucket type, and are employed for various purposes besides deepening the channels. They build the embankments and the "rip walls" or wing dams, as we would say, that jut out from the shores to confine the water in the channel.

Of these intercepting dykes or dams there are thousands. In fact, they may be said to be nearly continuous for hundreds of miles, 200 to 500 yards apart, and at low water they just show above the surface and are fully disclosed by the swash of passing steamboats. The banks of the Rhine are walled. It is not an exaggeration to say this, because natural banks between Mannheim and Cologne, if existing at all, are only short reaches where willows are planted. This protection by walls is necessary, because in so narrow a stream, where boats are driven at high speed, a hundred or more passing daily, the banks would soon be destroyed. In front of all cities these shore walls are of ashler work laid in cement. They are, however, of various character in other places, commonly of the "rip" kind, inclined at an angle of 1 : 2 or 1 : 3;

but in many cases where there are landings the walls are vertical or nearly so, and in the latter case are built with the stones "on edge," so to call it. This latter is a remarkable feature and worthy of remark, also of imitation. Such stones are usually laid flat or in loose walls, depending on gravity alone for stability; but by setting the same stones in a vertical position, or on their edge, they are wedged into position and firmly held against the waves or any other disturbing action.

The commerce of the Rhine is its most important fact. In our sparsely populated country it is impossible to conceive of a traffic produced by a highly industrial population of 400 or more to each square mile, and this I assume to be a fair estimate for the Rhine Valley. Belgium has 450 people to each square mile, and the Rhine Valley from Schaffhausen to Rotterdam must equal if not exceed this number.

Evidences of this enormous traffic are seen in various ways, especially between Cologne and Mannheim. Above the latter city the traffic is not great, because the larger steamers stop at that point. It is doubtful whether in any other part of the world goods are conveyed by water in so complete and economical a manner.

At low stages in the winter the water is but 9 feet deep in the channels, and the draft of boats is limited to about 7 feet. All the heavy traffic is conveyed in barges 200 to 250 feet long, built of iron or steel, and modeled in a highly scientific manner, with narrow beam not exceeding one-twelfth of the length. They are finely molded, so as to avoid resistance and disturbance of the water and to prevent injury to the banks. They are built with many water-tight compartments that have no communicating doors, and consequently are safe in case of accident. These barges are loaded low in the water, not exposing more than a foot of free-board, or just enough for buoyancy in case one compartment is filled with water.

From end to end, the top is covered with narrow movable hatches, so that any compartment or each alternate compartment can be wholly uncovered for lifting out or loading freight. Then the hatches are shifted over the loaded or emptied compartment, so the whole is practically an open vessel. The hatches interlock at the center, slope each way and form a close weather-proof deck or roof. There are neat cabins, hinged masts, with sail tackle and powerful steering gearing, anchors, winches and various other rigging, including sails, so that these barges are, in fact, complete navigating vessels.

The towing boats each draw two or three of these barges, mak-

ing up an immense cargo for the steam power expended and for the depth of the water. These boats are fine examples of constructive art, with lines but little less fine than those of the passenger steamers to be hereafter described. In most cases they are driven by inclined triple-expansive engines, connecting directly to center cranks, and are of the highest class. The boilers are in most cases of the type known as the Scotch marine, and fuel consumption is brought down to the lowest point attainable in powers of this extent. The paddle wheels are of the feathering type, and the whole system indicates evolution under long experience at the hands of highly trained engineers,—German, Belgian and Dutch, all these countries participating in the traffic.

Some idea of the amount of material conveyed may be formed from the fact that in this Rhine Valley is concentrated the great share of the industries of Germany, and that the fuel, as well as crude material and product must be carried out and in. The earthen-work industries are of an extent hard to imagine,—in brick, tile pipes, hollow ware, copings and a dozen more classes I cannot name. Between Mannheim and Köln are not less than twenty of these works, and one can see acres covered with finished material and from two to eight acres covered by the works or buildings.

Glass also forms a heavy and an enormous product of the Rhine country. Indeed, nearly all the main industries are directed to heavy products of one kind or another, and all have the air of being put down to endure.

I am sorry to be unable to furnish you with accurate statistics of these matters, but, as explained at the beginning, these notes are confined mainly to hurried observation.

The use of wire ropes on the Rhine boats is amazing. They seem to have supplanted the fibrous kind for nearly all uses. The towing-ropes employed for barges are of wire, about ½ inch in diameter and invisible at a little distance. They are from 200 to 400 yards long, and so light as to be always clear of the water, so that the barges seem to be following a course of their own independent of the towing steamers, and indeed do so to a great extent. Some screw towing boats are employed, and, to my astonishment, they seemed to perform very well, notwithstanding the shallow depth of water. I judged of this by the relative size of the barges and the number towed by the screw boats.

There are three companies that operate passenger steamers. My journey was made in one of the Rotterdam Company's boats that ply from Rotterdam to Mannheim. The other two companies

are in Cologne and Mannheim. The three companies have collectively about forty steamers. The towing boats can be numbered by hundreds, belonging in great part to private companies who own their own boats and barges.

Reverting again to some of the industries of the upper Rhine country, Mannheim has become a very great center of industry, because of its being at the head of navigation on the Rhine and because various industries have been founded there by citizens of other countries in order to escape the German tariff, on a method that we know something of in this country. Take the case of Messrs. Sulzer Bros., of Winterthur, Switzerland, as an example. They are extensive makers of steam engines of a very high class, and now employ about 4500 men. The German tariff, like all others, does not tax workmen or skill, and as soon as this customs law went into effect Sulzer Bros. sent men, tools, drawings and other equipment to Germany to make engines there, the "tariff" remaining in Winterthur, the same as much of our and the French customs taxes find their way to London. I visited these works of Sulzer Bros. at Mannheim, and I can bear testimony to the very high quality of the work done there, where about 1200 men are employed by this firm.

Mannheim and Ludwigshafen form practically one city, being on opposite sides of the Rhine, connected by a wonderful bridge, as are all Rhine bridges, especially those at Coblentz, Mayence and Cologne. In Mannheim and Ludwigshafen there is, to use a common phrase, a forest of chimneys, and the chimneys are not a disfigurement, but the contrary. To a visitor from this country, there is indeed nothing that is more striking than the industrial chimneys in Germany, Belgium and Switzerland. They are not square, with various degrees of taper and form, but always round, symmetrical, from 200 to 300 feet high, all of harmonious design, with elegant coping, entablatures and commonly are iron-bound at spaces of 15 to 20 feet.

I am of the opinion that the skill attained in Germany, especially in manipulative processes, now acknowledged to be among the most advanced, has been to a great extent an "overflow" from the adjoining cantons in Switzerland. There is, indeed, no question of this, and there is the problem; and it is one of some intricacy, how the Swiss have attained so much skill in a country without coal or iron and remote from the great lines of traffic. I gave to this subject such observation as was possible in the short time at command, and consulted engineers and owners at Zürich, Oerlikon, Baden and Winterthur, where are situated four leading machine

industries,—namely, Sulzer Bros., Brown, Bouveri & Co., Escher, Wyss & Co. and the Oerlikon Co., employing together about 12,000 men, all engaged on the finer classes of machine work.

Judged by the skill in evidence, the appearance of the workmen and of the works, with the harmonious relations that exist between the employers and the employed, and by a tolerably careful inspection of processes, I am inclined to believe that in no part of the world has skilled industry of this class been so well and thoroughly developed. Among the reasons for this, such as I could discover, are: (1) A complete system of education, secular and technical; (2) a strong predisposition of the people to mechanical pursuits, engendered no doubt by a struggle for comfortable existence where the areas capable of cultivation are limited and the climate unfavorable; (3) the existence all over the country of water power from numerous streams that descend toward the Rhine and lower-lying plains; (4) and especially, the fact that the enhanced price of fuel and iron forces the Swiss engineers to a higher class of work, in which skill is the principal component.

This last reason was given to me uniformly by a number of people who were consulted, and is no doubt the true cause of a very high development of skill in that country. No cheap work of any kind is made, and none in which skill is not a very considerable factor, if not the chief one.

Coupled with this high development of skilled industry in Switzerland, which I believe is not overestimated, are some facts of much interest to Americans. In Belgium, Holland and Germany one hears but little of America, but as soon as Switzerland is entered the whole changes. The English tongue comes into use again; one may with confidence assume that all the owners, engineers and managers not only speak English, but have been in America. I found myself in many cases corrected respecting firms and industries in the Eastern States. In the four great works I have named, nearly every one I met or conversed with had been In America, and in many cases to work here and learn our methods.

Mr. Henry Sulzer, who is head of the firm of that title, has three sons to inherit and conduct the business; one of them now in principal charge, and all of them well acquainted with American engineering practice. Carl Sulzer, the eldest son, could converse with me in excellent English concerning the various shops in this city, of the Yosemite Valley, Mount Shasta, Mount Tamalpais; indeed, had traveled from Puget Sound to San Diego and examined most things on this coast worthy of noting. I had the honor to be entertained at the house of Mr. Henry Sulzer, where there

was a company of nine, four of whom were ladies, and all were able to speak in English and knew more or less of America. While I was in Switzerland another son of Mr. Sulzer was in this city, on his way to Japan, where the firm has an agent and does a considerable business.

At the Oerlikon Works I was conducted through by the manager, who had been eleven years with the General Electric Company in this and other countries. At Escher, Wyss & Co.'s works my conductor was a son of the general manager, and, although quite a young man, had been all over this country. At Basel, Switzerland, I called on the veteran engineer Mr. Charles Brown, now retired from active service. He was for thirty years with the firm of Sulzer Bros., chief engineer there for most of that time. He will leave behind him a monument of successful work as great if not greater than any other man of whom I have knowledge. In speaking with Mr. Henry Sulzer, of the great works at Winterthur, he said: "Many men have had a part in building up these works. Mr. Brown has done a great part of it. We had less than one hundred men when he came in 1856." I also visited Brown, Bouveri & Co., who employ about 2000 men on electrical work pertaining to power transmission, and who are now putting down a large plant at Magdeburg, Germany, for the manufacture of the Parsons steam turbine. The capital of this company is to be about $5,000,000.

I had been informed that there was wear upon the vanes of these engines, but Mr. Charles Brown, Sr., said this was a mistake, and that no appreciable wear had appeared in any case. I had also been informed that the De Laval steam turbines had not been successful above 100 or 200 horse power. This also was a mistake, because the Oerlikon Company is erecting a new plant for this manufacture and has contracts now made for engines of large size; I think of several thousand horse power, and none of less than 500 horse power are to be furnished. The large-unit idea is now a ruling feature there in electrical generating plants. There are now in course of construction in Sulzer Bros.' Works at Winterthur single engines of 5000 horse power for a central plant in St. Petersburg, Russia.

What most of all attracted my attention in the Swiss works was the iron castings. They were perfect; not the slightest fault on any face, and their outline at least as true as the patterns. In the foundry processes, I could discover nothing peculiar except convenience, room, order, fine tackle for handling and a means of drying molds by hot air that I had not seen elsewhere. When a

mold is completed, a light furnace is set on top, and a current of air is forced through this furnace down into the mold, permeating it and removing the moisture from every part, also heating the mold before it is poured.

All duplicate work is done on molding machines, but, as Mr. Sulzer informed me, not to the extent that such machines are employed in the foundry of the Worthington Company at Elizabethport, N. J. The sand blast is in general use for cleaning castings, and is applied by very ingenious machines designed in that country.

The Swiss are a free-thinking and intelligent people. Their history shows how far personal rights are esteemed and preserved by all conditions of men. They are also given in the highest degree to association in all forms affecting their business and social interests, but the relation between the employers and their men seems to me to partake more of the co-operative sentiment than in other countries. The men are treated with much respect, which they demand and deserve. Mr. Henry Sulzer, chief of his firm, is in the works at 8 o'clock each morning, and leaves there between 6 and 7 in the evening, and this, I am told, is the custom of owners in other works of the country. He, his sons and all concerned in the works have the respect of the men in their employ, and they in turn are respectful in all dealings with their workmen, who are nearly all Swiss people.

Some years ago the firm built a "casino" or clubhouse for the workmen, containing hot, cold and vapor baths, a dining-room with heating and cooking appliances, a library and surgery. This was done not as a patronizing gift to the men, but as a necessary adjunct to the works. At Oerlikon the company is just completing a similar building, which I think would cost in this country from $30,000 to $40,000, perhaps twice as much. There are eighty plain bathrooms, several vapor baths, a surgery and other offices, as before mentioned, and, as I before pointed out, these are not heralded as patronizing "gifts" to the men, but are provided as a necessary part of the equipment, built out of profits that the men have earned. They have the management of these departments, and feel a proprietary interest in them.

It is nearly useless to indulge in homilies on the management of skilled labor or to attempt much improvement of the circumstances in a country so long as men are hired and paid by time, irrespective of what they perform or produce. Successful reform lies in the direction of education, responsibility, wages regulated by their product and a system that provides declared profits and an equitable incidence for taxation. Workmen in Switzerland, such

as work by time, receive only about one-half the rated wages paid here on this coast, but the real difference is much less than this and is indeed to a great extent made up by a difference in taxation and the cost of commodities and necessaries of life. When one wants to ascertain the rate of wages paid for skilled labor in any country, a "payroll" is not the thing to examine. That is surrounded by intricate conditions not open to the average observer. The true way is to examine the men themselves. Look into their faces, note their clothing and tools; go into their houses, see them on Sundays and holidays, and, above all, attend their meetings when labor and other problems are discussed.

Thus far the upper Rhine country has escaped labor discontent and disturbance, such as has occurred in other parts of Europe and in this country. Mr. Sulzer could inform me of but one strike in Switzerland, and that of unimportant extent.

Swiss enterprise is overflowing the Confederacy on the Italian side. At Milan, in Italy, is a very successful engineering plant, managed by a relative of Mr. Charles Brown, of Basel, who reports a fair degree of skill among the Italian workmen and an extreme interest in and devotion to the work, which has of course the charm of novelty to the Italian workmen.

I will add some remarks on the railways and highways of the Rhine country, including Belgium, where roadmaking has reached its highest development. It is in this feature that our country suffers most in comparison with Europe, owing in part to a want of wealth or taxable property along the highways, but also to methods that seem to me in many respects at fault. In comparison with those of Europe, our roads are only trails over the natural surface, with ditches at the sides to collect the water that runs off and convert it into a stream that goes on to do mischief in some manner. In Europe the roads are raised above the natural surface, and the water runs off at all points, is diffused over the land and causes no trouble.

Material for grading is taken from cuts or other sources, but, come from where it may, all roads are raised above the level of saturation, and thus are drained, so that no water stands on the surface, consequently they are always hard, and are not cut into ruts by wheels. The roads are always narrow, 10 to 12 feet wide, and this seems to be all that is required. The expense of construction and maintenance is much reduced by this, and we might learn a lesson from it in this country, although there is little hope of attaining a good system of highways under our present complicated system of diverse laws and means of taxation, also dearth

of skilled and responsible officers clothed with proper authority to direct such work, and, above all, the absence of a uniform system of construction.

In Belgium the principal roads are all paved in the manner known here as the "Belgian block system," consisting of cubes of hard stone, and are no doubt the most perfect highways to be found in any country of Northern Europe.

The Swiss railways are peculiar as compared with others in Europe, and many features may be noted by a stranger. The engines and trains are adapted to the loads to be carried. There are heavy wagons and locomotives, but these are not seen in the normal traffic. A passenger train for a certain number of people will not, I think, weigh more than half as much as in this country. The passenger carriages are very convenient, consisting of coupés with a corridor extending along the side, at the ends of which, for all classes, will be found closets and conveniences for washing. The carriages are warmed by steam, and this, as well as ventilation, is controlled by the occupants in each coupé. There is also electrical connection to the guard or officer in charge, and the windows do not slide up from the bottom, as in this country, but are let down from the top and stay where one puts them. The glass is bound around with a narrow rim of brass, that forms a guide, so that the windows are full width between the frames. These brass frames are planed, and slide noiselessly in grooves of wood.

It may seem that a narrow frame of brass would not form a support for the glass, but, if we think of the matter, neither does a wooden sash as we make them. When the glass is not in the sash, the latter is but a weak thing. The glass needs protection against torsion only, and this is provided for independently of the sash, which acts as a slide or guide.

Speaking of the weight of European engines and trains brings to mind some observations in this country during a recent trip by the Southern route from here to Washington city and back; also a previous trip a few months earlier out and back over a Northern route; respecting the enormous weight of everything pertaining to trains.

Engines of 100 tons are as common as those of 50 tons were twenty years ago, and the carriage weight per passenger must be at least 1500 pounds. The railways seem to be following the pace set by ocean steamers, perhaps with a like aim, but with infinitely more danger to those who travel. From Washington to this city, in the month of April, we passed five wrecks, one for each day.

Two were on the lines east of New Orleans, and three this side of New Orleans, and, as far as could be learned, these accidents all had their cause in the immense weights carried. In Georgia an engine of 200,000 pounds and a train to correspond had been run on a siding. The earth was soft from rain, and the permanent way was crushed, sleepers broken, rails bent and the train ready to topple over on its side. The tendency to greater weights seems to be due to an effort to increase earnings, but it must operate the other way. Lighter and more frequent trains, at higher speed, give a better and safer service, and correspond to the European system, where severe penalties follow careless administration of traveling facilities. The number of people injured and killed each year on American railways is reported to be from 25,000 to 30,000, or about fifty times as many as in Europe, including Great Britain.

I note that in Belgium, Holland, Germany and Switzerland the time schedules for railways always give the time of trains leaving stations, and not the time of their arrival, except at terminals. The advantage of this is that one does not have to ask how long a train will wait. The time shows that, and it is a comfort, especially as they always leave precisely at the time indicated. There is one new feature creeping into railway service there, the same as here, "*trains du luxe*" that charge extra because of speed. After purchasing a ticket from Zürich to Mannheim, I was called upon, when about half-way, for 2.5 marks for the "platz" or seat. I employed my highest powers in German to dispute this. "Schnellzug," said the guard. "Schnell!" said I "why, your train has not run at 40 miles an hour at any time through the day." It did no good, and I paid the "schnell" rate. It is a collusion of the continental railways, who have adopted this expedient of increasing rates, adding sleeping and dining carriages. Perhaps it is right, and letting one off with 2.5 marks is moderate, at any rate. The German Government has spent about 23,000,000 marks getting up these *trains de luxe,* and naturally wants to get some of it back again.

The German people especially will not submit to extortion. On the steamer out the passengers were mostly German, and prices had to conform to the standard. Cigars from 10 to 20 centimes, or 2 to 4 cents; wines, beer and other commodities were supplied at shore prices. The stores are procured in Belgium.

On the whole, traveling in Northern Europe is convenient and safe, not only from dangers, but from the arrogant treatment that seems necessary for the regulation of passengers on our own railways. The curtained Pullman sleeping carriages of our lines

seem to me far inferior to the *"schlafwagen"* of Germany and the Continent. We have, indeed, some evidence of this in the recent adoption of the same coupé system on some of the lines in this country.

The principal distinction of all is, however, in the cost of things. In our dining cars the common charge for a meal, or for the use of a table rather, is one dollar. In Europe it is for what you buy, down to five cents or less, and personal right is continually present in the fact that no one will permit himself to be cheated.

In conclusion, I will venture the opinion that our trade to Europe in skilled products is not likely to be permanent, and that it has been in the past a result of sudden and remarkable evolution in the arts, much more rapid than the conservative customs of our European friends would permit. There can be no profitable and permanent trade between nations of like civilization and skill unless based upon a difference of natural products, and, however greatly circumstances may for a time point to a different conclusion, the end must conform to inexorable economic laws. Cane sugar cannot long be produced in Louisiana by planting each year against tropical countries that plant once in four years.

The exportation of the smaller class of machine tools to Europe, which last year amounted to half a million dollars a month, has fallen to half this amount, owing in some degree to a very dull state of business in Germany and other North European countries, but more to the fact that the same machines are now produced there by the same methods we employ here, which have rendered export trade possible,—namely, an organized and extensive manufacture of duplicated products. They "make" machine tools in Europe. We "manufacture" them; but this same method is fast making its way in Northern Europe, and the principal center of activity is now and will probably remain in what may be called the upper Rhine Valley.

To one who was familiar with the circumstances of trans-Atlantic traffic between New York and European ports twenty years ago, it is a curious matter to note the changes that have been made since then. The character of the ships, their size and equipment and even the personnel of the crew are altered in such a degree that an old traveler feels at a loss respecting many things.

It has been my misfortune to have crossed the Atlantic about forty times in steamers instead of having been as often confined in jail for a like period, and the only comfort ever discovered in such a performance has been in observing the circumstances attending on this enormous traffic, that has no parallel in the world in its

volume, and perhaps none in the vicious weather that exists along the route that borders the Gulf Stream.

The aggregate value of the steamers now in service between the Atlantic ports and Europe is $250,000,000, and one-third of this amount is represented in express steamers sailing out of New York, carrying annually about 140,000 first-class and 500,000 steerage passengers; the latter coming mainly this way.

Of the companies owning and operating these steamers, eight have vessels valued as follows:

The Hamburg-American	$15,000,000
North German Lloyd	15,000,000
White Star Company	12,000,000
Cunard Company	10,000,000
Red Star and American	10,000,000
Atlantic Transport	10,000,000
Trans-Atlantic (French)	8,000,000
Holland-American	7,000,000

The principal line, the Hamburg-American, and the greatest in the world, has 109 steamers, with an aggregated tonnage of 600,000, all employed in trade to this Continent,—North and South America. The North German Lloyd is not much behind, with steamers amounting to 500,000 tons. These two lines employ about 12,000 people. Their capital shares are the same, $20,000,000 each, but this contains no water. On the contrary, it covers property of twice this value. They own their own piers at New York, worth $3,000,000. Other lines rent their piers, paying in some cases $200,000 a year.

The sails have disappeared, and we may say the sailors also. It is a steamboat problem now. The wind resistance of spars and sail tackle, at moderate rates of speed, far outweighs any propelling force that can be derived from canvas, to say nothing of the weight of such tackle and the expense of handling it.

The captain of the "Westernland," a Belgian steamer, built at Laird's eighteen years ago, told me that when the sails and their tackle were taken down from his ship and piled up on the quay, it seemed half a cargo, and, as this weight is carried at an average of 40 feet above the spar deck, one can imagine the effect on a vessel.

The only reasons left for the use of sails are the risk of failure of the machinery and to prevent rolling in a beam wind, and these reasons are nearly neutralized by the fact that duplicate units of machinery give almost complete assurance against disablement,

while rolling is to a great extent counteracted by bilge keels and by the great size and the form of the hulls.

It is common in this country to hear people speak of ocean carrying as an industry that is not profitable. The same remark was made by Æsop's fox that could not reach the grapes. Ocean carriage does pay, and it never before paid as it does now. On a late voyage, the "Ivernia," of the Cunard Line, earned $50,000, and her expenses, all told, were $20,000. I think she is about 10,000 tons capacity. The "Celtic," now building at Belfast, is over 20,000 tons, and the Germans are busy building like vessels. The rates of carriage are now uniform or nearly so, and such ships are like a gold mine,—a good one, I mean.

Last year the Hamburg-American Company earned a dividend of 10 per cent., the North German Lloyd 8½ per cent. and the White Star Company 15 per cent. on their capital shares.

The United States Commissioner of Navigation, in his last report, says about 30,000 tons of shipping owned by Americans is sailed under foreign flags. This does not look like an unprofitable business. The American Line—that is, the four ships, or three at this time, sailed under the American flag—makes up our part in this great trans-Atlantic fleet. The Red Star Line, which for advertising purposes is included in the title, is Belgian, in fact, with headquarters in Antwerp, but several of the steamers in this service are British. The "Kensington" and "Southwark," 600 feet long, that carry 8000 tons of freight, are British, and two new vessels building for this line will no doubt be sailed under the same flag. The British owner does not care where his vessel serves, so long as she sends the profits to London or Glasgow.

The "Southwark," on which I went out to the Continent in March last, was loaded at and sailed from the American Line dock, but I noted that the crew were British; and as soon as the lines were cast off the English ensign was run up, and from that on we were in a British ship.

Past President Mr. G. W. Dickie has explained before this Society in part, but not fully, some of the causes that lie at the bottom of our humiliating position in the ocean carrying trade, and the effects of our antiquated navigation laws, but he has not, that I am sure of, exposed the fallacy of the reasons commonly assigned for this state of things.

In the first place, every one here knows that, sailing out of this port, we have but one deep sea line under the American flag, and that a subsidized one. We see here German, British, Japanese and other foreign flags in many cases on our American-owned vessels.

This should be enough to indicate to every one some fundamental error in our laws relating to shipping. Capital is invited to this country for all other purposes, but no foreigner can own any part of an American ship, and not even an American can who resides usually abroad. Our people can buy and import anything by paying the duty, except ships and obscene books. These are absolutely excluded. An American ship that is disabled abroad and has repairs done must on her return home pay a duty of 40 per cent. on the amount expended; a vessel once sold to a foreign owner can never be bought back again, with much more of a like nature that I will not consume time to describe.

In 1861 American tonnage almost equaled that of Great Britain,—about 5,000,000 tons. Twenty years later it was one-fifteenth as much, and the decline was not much greater during the Civil War than before and after that.

Here and in many other States deep-water ships are taxed as personal property. A vessel must pay for sewers, lights, police, streets and other municipal expenditures, but does not use them, and when she comes home cannot land or unload except by paying high charges for lying at the docks which she has been taxed to build. This subject need not be pursued. Those interested will find the matter fully treated in "Our Merchant Marine," by David A. Wells, now, I believe, an officer of the Revenue Department. The preface of his book begins as follows:

"The expulsion of the Moors and Jews from Spain and the repeal of the Edict of Nantes, which deprived these countries of their artisans and industries, have been accepted by all historians and economists as the most striking examples in modern times of great national disaster and decay, directly contingent on unwise and stupid, but at the same time deliberately adopted, state policies.

"It has been reserved for the United States, claiming to be one of the most enlightened and liberal nations of the world, after an experience of nearly three hundred years since the occurrence of the above precedents, to furnish a third and equally striking and parallel example of results, contingent in like causes, in the decay and almost annihilation of her merchant marine and ocean carrying trade,—a branch of her domestic industry that formerly ranked in importance second only to her agriculture."

Returning now to German companies, about 1875, or something later than this (I have not the reference at hand), the great Chancellor Bismarck proposed to subsidize German shipping as the French had done, with a view to its expansion. This called out from the Hamburg merchants, through their Board of Trade, a

memorial to the government, which, tersely translated, means "Please let our shipping alone. We will take care of that." "History shows that attempts of this kind have an effect opposite to that intended," and so on. A careful translation of this memorial can be found in the book above mentioned.

The result is before us. The French subsidies have done no good and much harm. How often do we see a French ship in our port? German shipping, without subsidies, has undergone a phenomenal development. The Germans have the second place in number, and the greatest ships that come into our ports. The express ship "Deutschland" is believed to be the fastest. She burns 600 tons of coal a day, steams 500 or more miles and carries comparatively no cargo,—only 600 tons. She is an advertisement, but pays a profit besides.

The North German Lloyd Company is building, at Settin, two ships to run at a greater speed. In this country, the Great Northern Company is building, in New London, Conn., two ships 630 feet long, 73 feet beam, to carry over 20,000 tons each. These steamers will sail from Puget Sound ports, and no doubt under the British or some other foreign flag.

At the Union Iron Works here and at the East are being built very large steamers to run from this port. The "Korea," of 18,000 horse power, 572 feet long, was launched at Newport in March. Two of 12,000 tons each are building here.

All large ships are now provided with double screws. This is essential on account of insurance rates alone, even if there were not many other reasons. It divides the weight of reciprocating parts and permits a correspondingly higher rate of revolution, without excessive risk and wear. One ship I traveled on recently had a low-pressure cylinder 93 inches in diameter, with a piston and connections that weighed 20 tons. This mass moved at the rate of 700 feet per minute, and was reversed 140 times per minute. The strains can be imagined. The duplicate power units give more room, because placed at the sides of the ship, leaving a wide room between, into which light can enter from the engine hatches.

There is much wonder at this time that the British companies do not keep up the speed of their vessels to that of the German lines. This, I think, can be accounted for, in part at least, by an expectation that the turbine engine will soon be a means of propulsion. The *Viper* and *Cobra* gunboats are now driven by engines of this type at a speed of 37 miles an hour, and a small steamer now building at Dunbarton for Channel service is to be fitted with these engines.

Twelve or more years ago I ventured the prediction before this Society that rotative engines and pumps would supplant in time the reciprocating type, and I feel some confidence in this prophecy, owing to the fact that certain Swiss firms at this time are preparing to set at work over 2000 men on turbine engines. In pumping fluids there is the same promise. Rotative turbine pumps now raise water against a pressure of 300 pounds per square inch. The two problems of receiving and applying the dynamic energy of moving fluid and imparting motion and energy to the same fluids are in many respects analogous. This is especially true of liquids, and the two would fall equally under the same mathematical laws were it not for centrifugal force, which performs a considerable part in the action of the latter-named class of machines. A manufacture of these will be commenced in this city before long, and I hope in due time to present here some of the very interesting features that are being developed in Europe and in this country.

Mr. Dickie: I rise on your order, although I doubt my ability to say anything in regard to this very interesting paper, except to express the interest with which I have listened to it.

The field covered by the paper is so wide that discussion of it is hardly possible. I followed Mr. Richards closely while he was reading, and on many things I could agree with him, while on some things I could not.

Last year I spent a little while in Germany, and noted a great many things that Mr. Richards mentioned, especially the movement that was going on there for the manufacture of machines and engines that had hitherto been built as individual designs.

Very large establishments have been recently brought into operation, embracing the very newest methods of production, and using the best known tools and methods of work. What one might call the humanities of manufacturing seems to have reached a very high development there. I visited establishments where every one of the thousands employed might have his daily bath in the works and a table to eat his lunch at in a great dining hall.

Somehow, that sort of thing does not go very much here. Our men look upon it as a kind of paternal management that needs to be resented. Such provision made for our men here only prompts them to inquire where we got the money to provide it; and this inquiry is usually answered by the labor organizers who tell them that it is stolen from their labor, with the advice to demand more wages and buy bath tubs for their homes, and shorter hours, that the may have time to use them.

I agree with Mr. Richards in regard to the short life that is likely to be the result of what is now called "American competition" with Europe. When these people get fairly into the methods of manufacture they are now adopting, they will produce as much per man per day as we do; and we will then be in luck to hold our own markets.

I cannot agree with Mr. Richards in what he says in regard to the comfort of railroad travel in Europe, compared with the comfort of traveling on American railroads. My opinion is that you can travel from San Francisco to New York with less discomfort, and arrive fresher at your destination, than you will experience in traveling from Paris to Berlin.

I think most of what Mr. Richards says about American shipping is true. I have stated here before, and often, that we are not likely to become a great ship-owning country until wiser legislation prevails in regard to ship owning. Municipal and state taxation of ships should be abolished throughout the whole country. A new art cannot be built up on being taxed. This is true the world over, and as long as the tax gatherer has his fingers on the throat of our shipping it will not succeed.

Is it not absurd that the city of San Francisco, which is an inland town, with no harbor nor any water front, may tax a ship in mid-ocean to support the city government; build and mend streets, sewer and light them, simply because the name of that ship is registered in a building on one of her streets called the Custom House?

Last year there was a proposition to build a new Custom House for San Francisco, and to build it on the sea wall instead of on Battery street. Had that been done, our ships would have escaped municipal taxes, for then they would be registered in the State and not in the city.

Few people know that this is an "inland" city built near a harbor of the same name. This city terminates 150 feet from the water front. Beyond that line San Francisco officials lose their authority. Only one is allowed to cross with authority and that is the tax collector.

It is unfortunate that our people cannot be made to realize this. If they did there would be no rest until the harbor of San Francisco would be free to every ship built and owned in this State, and no municipal or State taxes imposed on ocean-going ships.

Editors reprinting articles from this journal are requested to credit not only the JOURNAL, but also the Society before which such articles were read.

ASSOCIATION OF ENGINEERING SOCIETIES.

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THE PITOT TUBE; ITS FORMULA.

BY WILLIAM MONROE WHITE, B.E., MEMBER LOUISIANA ENGINEERING SOCIETY.

[Read before the Society, May 13, 1901.*]

THE writer had the pleasure of delivering before the Louisiana Engineering Society on October 8, 1900, a paper entitled "Water Measurements in Connection with a Test of a Centrifugal Pump at Jourdan Avenue Drainage Station." Professor Gregory, of Tulane University, wrote an article on the same series of tests, which was read before the American Society of Mechanical Engineers at the December meeting in New York city. The water measurements of these tests were largely made with the assistance of the Pitot tube. In our use of the Pitot tube, its formula was taken as $V = \sqrt{2gh}$.

At the reading of Professor Gregory's paper Mr. William Kent, author of "Kent's Mechanical Engineer's Pocket-Book," severely criticized this formula, and said that the true formula is $V = \sqrt{gh}$. In his criticism he said:† "I am especially interested in this paper, for the reason that some of the experiments and deductions in it constitute the best experimental proof that I have yet seen of the inaccuracy of the formula quoted in the last line of the first page of the paper; that is, the time-honored formula $V = \sqrt{2gh}$. It is a perfectly correct theoretical formula when the velocity is produced by the head, but it is incorrect when the head is

*Manuscript received June 15, 1901.—Secretary, Assn. of Eng. Socs.

†Transactions of the American Society of Mechanical Engineers, vol. xxii, p. 284.

produced by the velocity, and the proof of the last statement is shown in the paper in the most satisfactory way I have ever seen.

"Take the Pitot tube. Several writers on the Pitot tube have said that the proper formula for it is $V = \sqrt{2gh}$, but the experiments in this paper proves that it is not correct. The correct theoretical formula is $V = \sqrt{gh}$ or $H = \frac{V^2}{g}$, and the correct practical formula is $H = C\ \frac{V^2}{g}$, in which C is an experimental coefficient, always less than unity, whenever the head is the effect produced by the velocity. I have never seen a better statement of how to test the Pitot tube than the one given in the paper. I do not know a better method than to put one in a canal where there is no current and tow it in a boat at a uniform velocity. The author obtained in his experiment $V = .849\ \sqrt{2gh}$, which, transposed, is $H = 1.39\ \frac{V^2}{2g}$, or 39 per cent. greater than the head, which many writers on the Pitot tube say is the theoretical head that can be produced by the velocity. If we take the correct formula we obtain $H = .695\ \frac{V^2}{g}$ in which .695 is the coefficient of efficiency of the tube. The difference between .695 and unity is the loss of head in the Pitot tube, due to eddies or to the currents not striking it squarely, and being deflected at right angles to its orifice. It is well known that the pressure produced by a jet striking a blade at right angles to the jet is theoretically equal to twice the head which would produce the velocity, or $2 \times \frac{V^2}{2g}$. We would get the same result on the Pitot tube, provided the jet would strike it fairly and leave at right angles, which it does not do. As one of the speakers said, we can have no confidence in the Pitot tube unless it is standardized every time it is used. The Pitot tube thus standardized would be an excellent instrument for testing the velocity of water flowing at a uniform speed. But in no current, stream or pipe is there such a thing as uniform velocity of water, so that even if you have the Pitot tube properly standardized, the next question is how to use that and get the average velocity of water through the pipe. This is a matter of great difficulty, and has to be done by taking the velocity at different points of the area and making a computation by the aid of the calculus to find the average velocity.

"This theoretical formula, $H = C\,\frac{V^2}{g}$ applies to centrifugal pumps, Pitot tubes, centrifugal fans and windmills, and generally to all cases in which the velocity of a current is the cause and the head is the effect; while $V = \sqrt{2gh}$ is the correct formula where the head is the cause and the velocity is the effect."

Let us examine Mr. Kent's transposition of the formula $V = .849 \sqrt{2gh}$. The transposition is $H = 1.39 \frac{V^2}{2g}$. Mr. Kent's reasoning, by which this formula is made to appear as giving the Pitot tube an efficiency greater than 100 per cent., would be perfectly rigid if H were the value of the *velocity head alone*. The Pitot tube under discussion is made according to the Darcy principle, with two glass tubes connected to a common vacuum. One tube is connected to the nozzle, and gives the velocity head; the other is connected to the rear part of the tube, and is supposed to give the hydraulic head. H is not only the velocity head, then, but is made up of two readings, being the difference of two water levels. One reading is the velocity head, the other may or may not be the hydraulic head; its value may be above or below the hydraulic head. If a suction action takes place about that part of the tube which is supposed to measure the hydraulic head, the hydraulic head is decreased and the value of H is increased. The value of H for the tube which was used on the test is $H = \frac{V^2}{2g} + .39 \frac{V^2}{2g}$. The last term in the equation is the value, in terms of velocity head, of the suction action at the hydraulic part of the tube. The writer gave the reason for the introduction of the constant ϕ in his paper read before the Society last October.

In looking up the authorities on the subject of the Pitot tube, the writer finds quite a diversity of opinion as to its formula. Weisbach writes the equation "$V = \mu \sqrt{2gh}$, or, more simply, $V = \psi \sqrt{h}$," and states that "with fine instruments, when the velocities were between .32 and 1.24 meters, we found $V = 3.545 \sqrt{h}$ meters." J. T. Fanning writes the equation $V = \sqrt{C2gh}$. Mr. Church, author of "Mechanics of Engineering," gives the theoretical formula as "$H = 2 \frac{V^2}{2g}$, or $V = \sqrt{gh}$."

The following theoretical consideration is taken from Church's "Mechanics," page 801 (the writer uses Church's "Mechanics" because it is the one which he studied while at college, and is the one with which he is most familiar):

"IMPULSE OF A JET OF WATER ON A FIXED CURVED VANE (WITH BORDERS).

"The jet passes tangentially upon the vane (Fig. 1); B is the stationary nozzle from which a jet of water of cross-section F (area) and velocity V impinges tangentially upon the vane, which has plane borders, parallel to paper, to prevent the lateral escape of the jet. The curve of the vane is not circular necessarily. The

vane being smooth, the velocity of the water in its curved path remains = V at all points along the curve. Conceive the curve divided into a great number of small lengths, each = ds, and subtending some angle = d Φ from its own center of curvature, its radius of curvature being = r (different for different ds's), which makes some angle = Φ with the axis Y (at right angles to original straight jet BA). At any instant of time there is an arc of water, AD, in contact with the vane exerting pressure upon it. The pressure dP of any ds of the vane against the small mass of water F ds $\gamma \div$ g then in contact with it is the 'deviating' or 'centripetal'

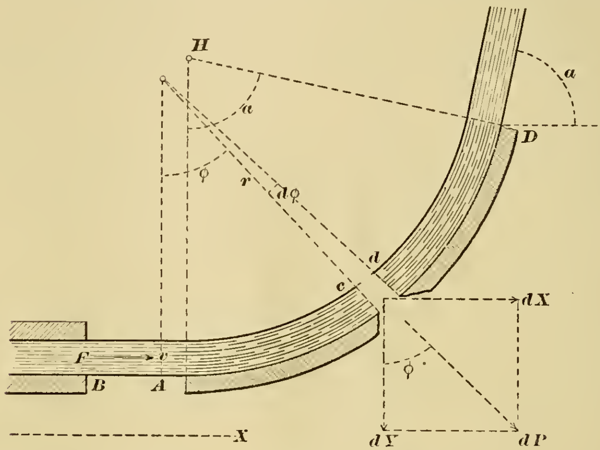

FIG. 1.

force accountable for its motion in a curve of radius = r, and hence must have a value

$$dP = \frac{F\gamma ds}{g}\frac{V^2}{r}. \qquad (1)$$

"The opposite and equal of this force is the dP shown in Fig. 1, and is the impulse or pressure of this small mass against the vane. Its X-component is dX = dP sin Φ. By making Φ vary from 0 to a, and adding up the corresponding values of dX, we obtain the sum of X-components of the small pressures exerted simultaneously against the vane by the arc of water then in contact with it,—*i.e.*, noting that ds = rd Φ,

$$\therefore \int_{\Phi=0}^{\Phi=a} dX = \int_0^a dP \sin\Phi = \frac{F\gamma V^2}{g}\int_0^a \frac{ds \sin\Phi}{r}$$

$$= \frac{F\gamma V^2}{g}\cdot\int_0^a [\sin\Phi]\, d\Phi = \frac{F\gamma V^2}{g}\left[\overset{a}{\underset{0}{-}}\cos\Phi\right] \qquad (2)$$

hence the X-impulse against fixed vane $= \frac{F\gamma V^2}{g}$ [1 — cos a] (3)

"For a fixed plate, then, Fig. 2, at right angles to the jet, we have for the force or impulse (on the plate) (with a $= 90°$; then cos a $= 0$) and

$$P = \frac{F\,V^2}{g} r. = 2\,F.\frac{V^2}{2g.} r. \qquad (4)$$

"The experiments of Bidone, made in 1838, confirmed the truth of equation (4) quite closely, as do also those of two students of the University of Pennsylvania in 1887.

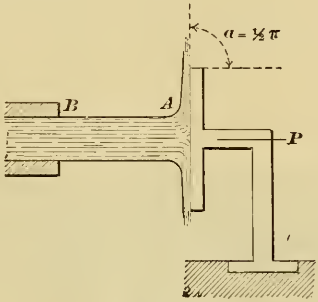

FIG. 2.

"Equation (4) is applicable to the theory of the Pitot tube, if we consider the edge of the tube plane and quite wide. (Fig. 3.) The water in the tube is at rest, and its section at 'A' (of area = F) may be treated as a flat vertical plate receiving not only the

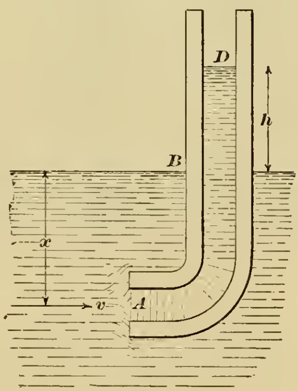

FIG. 3.

hydrostatic pressure Fx r, due to the depth x below the surface, but a continuous impulse

$$P = F\,r\,V^2 \div g \quad (5).$$

For the equilibrium of the end A of the stationary column AD we must have, therefore,

$$Fxr + \frac{F\,V^2 r}{g} = Fxr + Fhr; \textit{ i.e.}, \; h = (2.0)\,\frac{V^2}{2g}."$$

Mr. Church's reasoning holds good about the pressure on a flat plate being $2F\frac{V^2}{2g}$, but he is wrong when he applies that reasoning to the Pitot tube. He assumes that a jet of area A (Fig. 3) exerts its whole force upon the equal area of the tube. If this be true, why should the walls of the tube be "plane and quite wide"? Is it that they take a portion of the pressure P? They cannot, or the pressure would be divided between A and the walls of the tube.

If the tube (Fig. 3) should receive the whole impulse of a jet of the same area A, the whole force exerted upon the tube at A would be $P = 2\frac{V^2}{2g}F$. The 2 in the equation would not belong to F, because the areas are the same; therefore, it must belong (if the above reasoning is true) to the $\frac{V^2}{2g}$. If we place the 2 before $\frac{V^2}{2g}$, we say that a head h will cause a velocity head $\frac{V^2}{2g}$, but that a velocity head $\frac{V^2}{2g}$ will cause a head 2h, which, of course, cannot be, for the same reason that a pendulum loosened on one side of its swing will not rise to a greater height on the other. But the area of the jet and the area over which it acts cannot be the same, because the formula deduced depends for its solution upon the existence of a radius of curvature of the jet at striking the plate. If this radius be reduced to 0, the solution of the equation would be impossible. Therefore, the radius r must exist, and the area over which the jet acts is greater than the area of the jet. I submit, therefore, that the equation as deduced by Mr. Church should be less than $h = 2\frac{V^2}{2g}$, and that it depends for its value upon the maximum pressure per unit of area on the plate. We would expect the greatest pressure per unit of area to be $h = \frac{V^2}{2g}$.

From the solution of the equation we see that the pressure on the plate extends over an area greater than the area of the jet. The first thing to do, then, in arriving at the formula is to find the relation between the area of the jet and the area of the plate over which it acts, and next to find the distribution of the pressure on the plate and the greatest pressure per unit of area.

EXPERIMENT I.

A Round Jet of Water Impinging on a Flat Plate.

The object of this experiment is (1) to determine the pressure on a plate of a round jet of water of known area and velocity impinging on the plate; (2) to determine in what manner the pressure

of the jet is distributed on the plate; (3) to determine the greatest pressure per unit of area.

Apparatus. The apparatus used in this experiment is as follows: (Fig. 4.) One end of a rectangular wooden box, 18 x 32 x 60 inches, is fitted with baffling plates, over which and under which the water must pass in reaching the center. A hose discharging into the end of the box creates eddies, but the water in flowing past the baffling plates becomes quiescent by the time it reaches the center of the box. A hole 6 inches in diameter is in the center of the floor of the box. Over this hole are fitted the different orifices used. The orifices are plates of brass and iron of 1-16-inch thickness, each with a round hole in the center. The upper edges of the hole are filed to a knife-edge, making a clean, sharp orifice. The

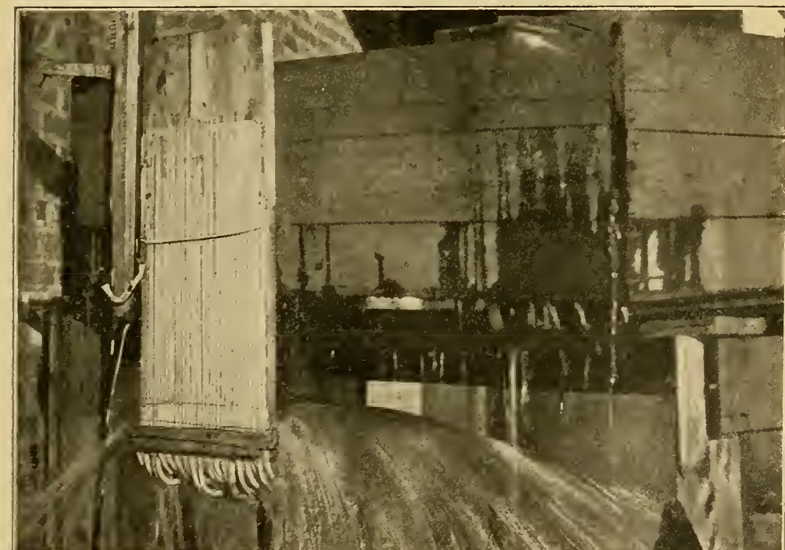

FIG. 4.

plate (Fig. 5) upon which the jet impinges is $\frac{1}{2}$ inch thick by 8 inches in diameter, and is of aluminum. Thirty-three 1-16-inch holes are drilled in its upper surface. They lie on fifteen concentric circles, whose radii differ from each other by increments of $\frac{1}{4}$ inch and vary from $\frac{1}{4}$ to $3\frac{3}{4}$ inches. One hole is in the center, and two holes are on each circle, except the one of 2-inch radius, which has four holes about equally spaced from each other. The holes all lie as nearly along one diameter as it was convenient to place them. Each hole, 1-16 inch in diameter, leads into a nipple, $\frac{1}{8}$ x 3 inches, screwed into the bottom of the plate. The nipples are connected by

rubber tubes to vertical glass tubes (see Fig. 4). Behind the glass tubes is a scale reading in tenths of an inch. When the water fell through the orifice, it was noticed that a whirling action was set up in the jet, tending to distort it. In order to overcome this, 1-32-inch plates were placed vertically above the orifice. These plates broke up any small eddies, and the water fell in a very quiet stream onto the plate below. The plate was placed exactly level and so that the jet struck it in the center. The pressure on the plate forced water through the 1-16-inch holes and through the nipples into the glass tubes. The height of the water in each of these tubes, above

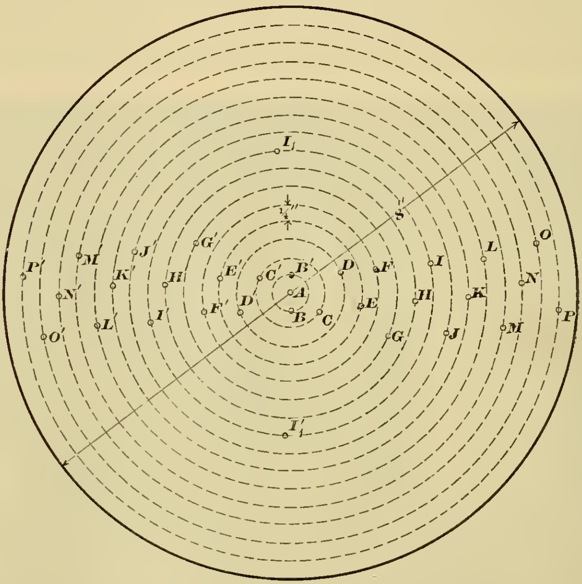

Fig. 5.

the surface of the plate, was the pressure in inches of water on the plate at the hole to which the tube was connected. The holes in the plates are lettered for convenience of reference (Fig. 5). The center hole is A. The holes along one-half of the diameter are lettered from B to P, inclusive, and those on the other half of the diameter from B′ to P′. The two additional holes on the circle of radius 2 inches were lettered I_1 and I'_1, respectively. The pressure, given by the reading of the tube connected to the center hole A, is supposed to extend over the area of a circle of $\frac{1}{4}$ inch in diameter. The pressure given by the hole B is supposed to extend over the area of a $\frac{1}{4}$-inch circular strip of $\frac{3}{4}$ inch outside diameter and $\frac{1}{4}$ inch inside diameter, and so on. The area corresponding to each letter is given in Column 6, Table I.

TABLE I. OBSERVATION 1.

Orifice=3″. Height of water in box above orifice=2.85″.
Diameter of Jet at Plate=1.78″. Area=2.49 sq. in.
Height of Orifice above Plate=10.5″. Total Fall of Water=13.35″.
Velocity of Water at Plate from $V=\sqrt{2gh}=8.45$ ft. per sec.

1	2	3	4	5	6	7	8	9
	Scale Readings in Inches.							
Tubes on Scale.	Height of Water in Water Box.	Pressure on Plate in Inches of Water. A to P	Pressure on Plate in Inches of Water. A to P′	Average (3 and 4).	Areas of Annular Strips A to P in Square Inches.	Areas (6) × Average Pressure A to P (Sq. in. × in.)	Total Pressure on Plate required to change the direction of Jet.	2 × Area of Jet × h — the distance the water falls.
A	13.35	13.25	13.25	13.25	.049	.649		
B	13.35	13.25	12.35	12.80	.3928	5.027		
C	13.35	12.20	12.55	12.37	.7854	9.720		
D	13.35	11.25	9.10	10.15	1.1781	11.950		
E	13.35	9.10	7.70	8.40	1.5707	13.190		
F	13.35	6.80	3.05	4.92	1.9635	9.650		
G	13.35	3.40	1.70	2.50	2.3561	5.880		
H	13.35	1.65	.60	2.12	2.7494	5.820		
I	13.35	.65	.50	.57	3.1420	1.791		
J	13.35	.35	.40	.37	3.5330	1.207	64.874	66.5
K	13.35	.30	.25	.27	3.9280	1.058		
L	13.35	.30	.20	.25	4.3240	1.080		
M	13.35	.30	.15	.22	4.7080	1.035		
N	13.35	.20	.20	.20	5.1050	1.020		
O	13.35	.20	.15	.17	5.4980	.935		
P	13.35	.20	.10	.15	5.8890	.895		
I_1	13.35	.65	.55	.60	3.1420			

In determining the pressure on an area, an average of the readings BB′, CC′, etc., was taken. By multiplying the average pressure by the area of the corresponding strip, the total pressure on the annular strip was determined. This pressure is given in Column 7, Table I, and is given in inches of water pressure per square inch of surface, or in cubic inches. The total pressure on the plate is obtained by summing up the pressures on the several annular strips. In Table I it will be noticed that the pressure is integrated only so far from the center as it is seen that the jet really exerts any pressure. The remaining pressure from this point to the edge of the plate is due to the dead weight of the water. An inspection of the curve of pressure of Observation 1, Fig. 6, shows this clearly. The pressure on the plate from the center to the circle J is the pressure necessary to turn the jet, but the pressure from J to P is only the weight of the water as it flows off the plate. The manner in which the pressure of the jet is distributed on the plate is shown by the curves 1 to 11 (Figs. 6 to 17). The irregularities in the curves, Figs. 1, 2, 3, 4 and 8, are caused by the jet not being quite in the center of the plate. The remaining curves are smooth and are of exactly the same form, showing that the curve of pressure on the plate obeys the same law, whatever the diameter of the jet or its velocity upon striking the plate.

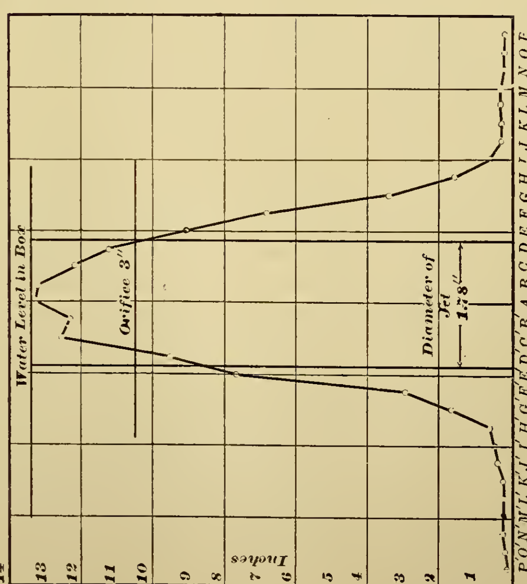

Fig. 6. Observation I. Curve of Pressure on Plate in Inches of Water.

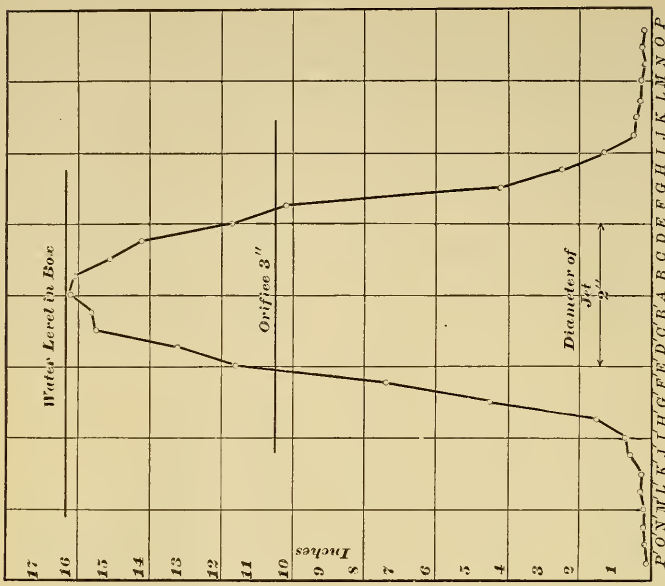

Fig. 7. Observation II. Curve of Pressure on Plate in Inches of Water.

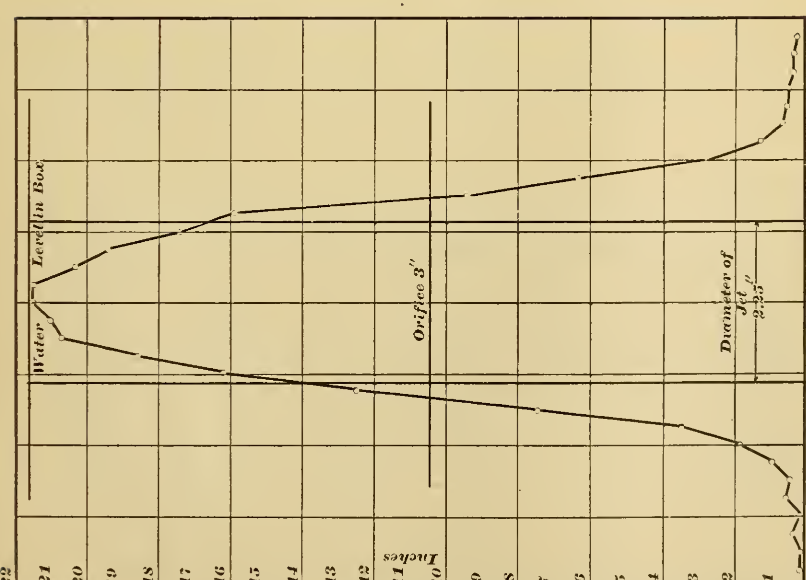

Fig. 8. Observation III. Curve of Pressure on Plate in Inches of Water.

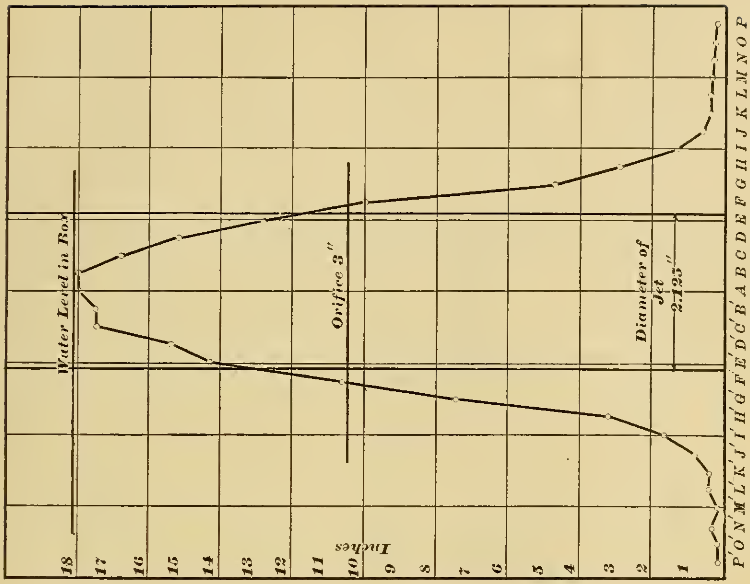

Fig. 9. Observation IV. Curve of Pressure on Plate in Inches of Water.

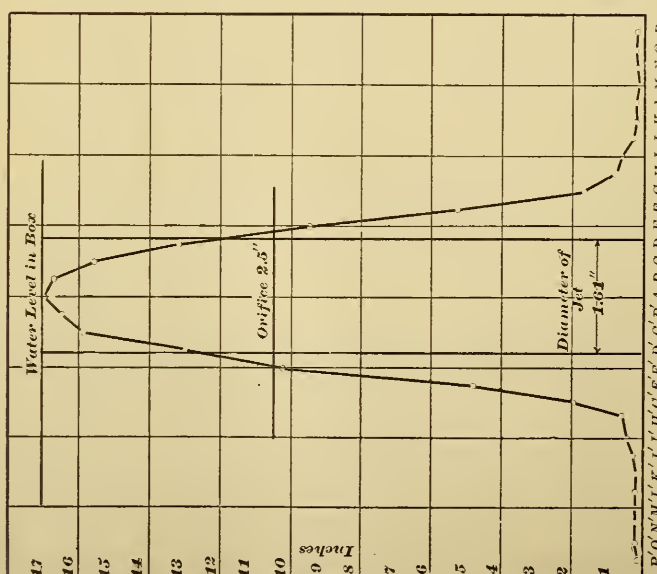

FIG. 10. OBSERVATION V. CURVE OF PRESSURE ON PLATE IN INCHES OF WATER.

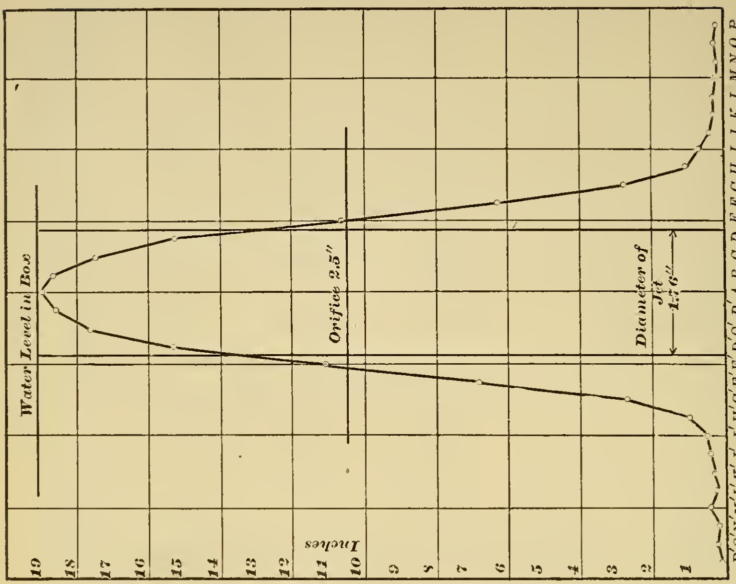

FIG. 11. OBSERVATION VI. CURVE OF PRESSURE ON PLATE IN INCHES OF WATER.

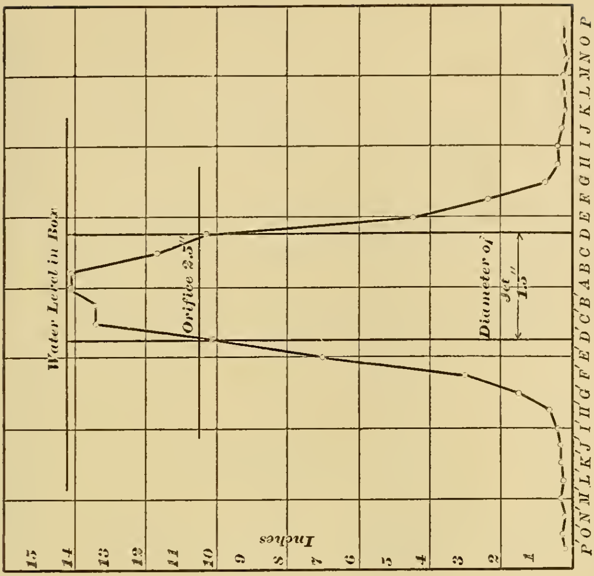

FIG. 13. OBSERVATION VIII. CURVE OF PRESSURE ON PLATE IN INCHES OF WATER.

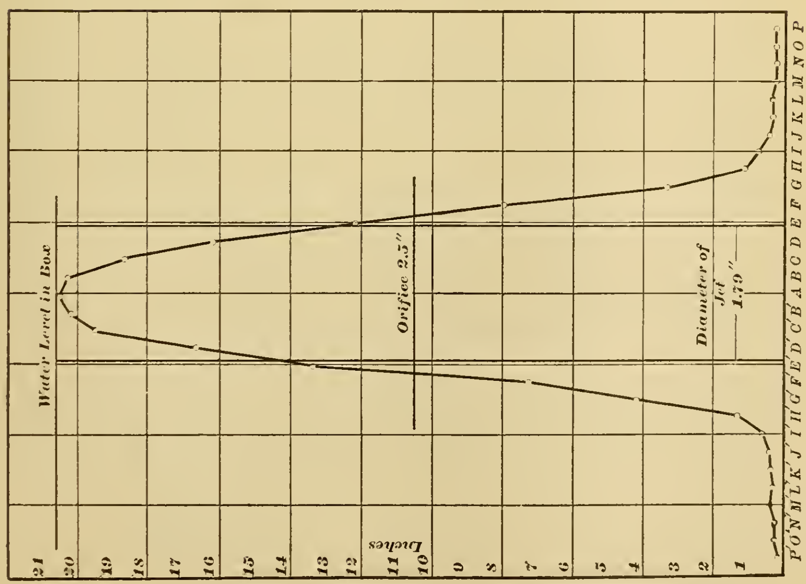

FIG. 12. OBSERVATION VII. CURVE OF PRESSURE ON PLATE IN INCHES OF WATER.

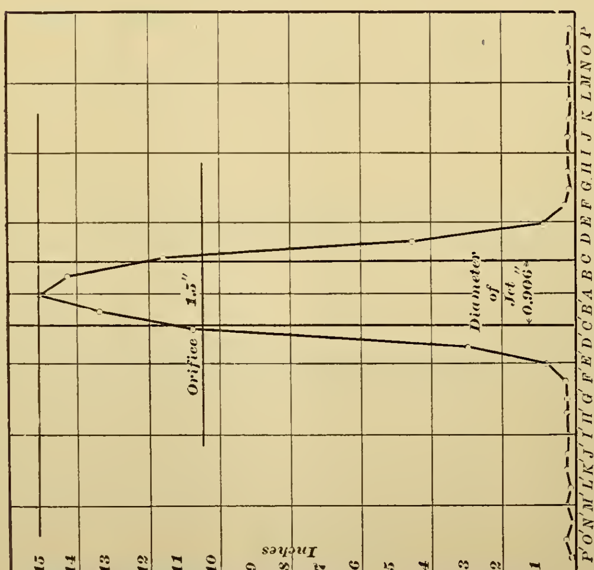

Fig. 14. Observation IX. Curve of Pressure on Plate in Inches of Water.

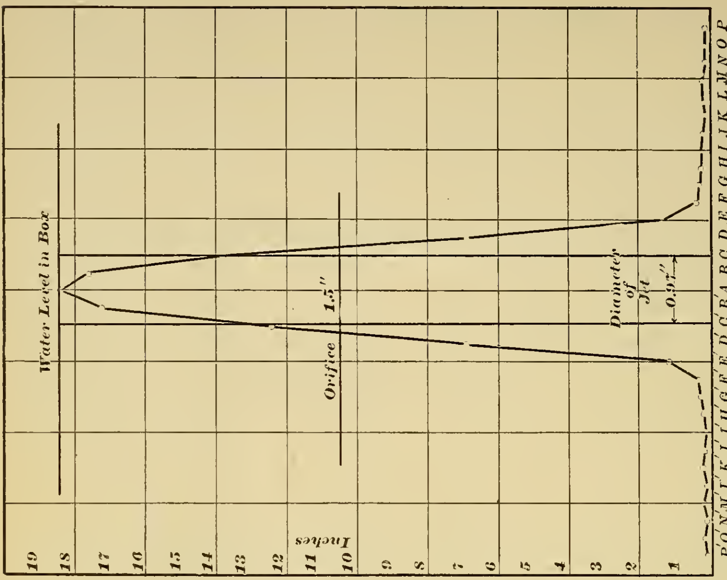

Fig. 15. Observation X. Curve of Pressure on Plate in Inches of Water.

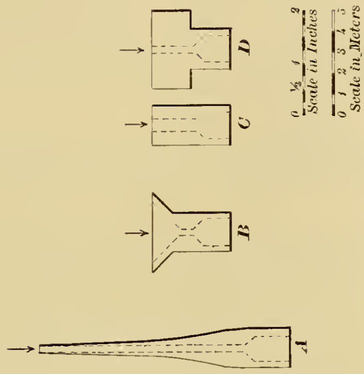

Fig. 17.

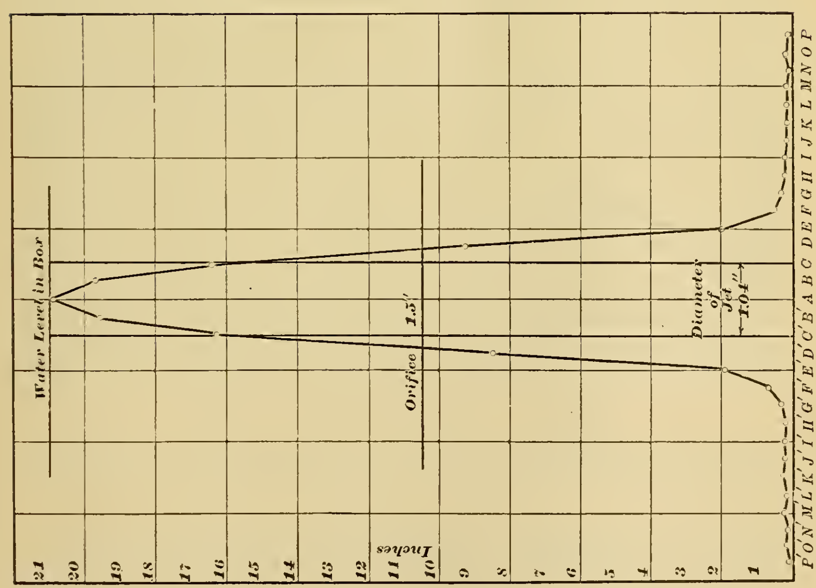

Fig. 16. Observation XI. Curve of Pressure on Plate in Inches of Water.

TABLE II.

1. Total pressure of jet impinging on a plate, in inches of water.
2. Greatest pressure per unit of area.
3. Area of plate over which jet acts.

1	2	3	4	5	6	7	8	9	10	11	12	13
Observation.	Orifice (Inches).	Height of Water over Orifice (Inches).	h = the Distance from Water Surface to Jet (Inches).	Velocity of the Jet at the Plate from $V=\sqrt{2gh}$ g=32.2.	Diameter of the Jet at the Plate (Inches).	Area of Jet (Sq. in.).	Area × h (Sq. in. × in.).	Observed Pressure on the Plate (Sq. in. × in.).	$\frac{\text{Obs. Press}}{\text{Area} \times \text{h.}}$ ●	(Compare with 4.) Greatest Pressure per Unit of Area in Inches of Water (Inches).	Total Area over which Jet Acts (Sq. in.).	$\frac{\text{Total Area}}{\text{Area of Jet.}}$ ●
1	3.0	2.85	13.35	8.45	1.78	2.7900	33.25	64.874	1.95	13.25	21.6	7.7
2	3.0	5.76	16.26	9.34	2.00	3.1450	51.10	91.640	1.80	16.22	17.7	5.6
3	3.0	13.10	21.60	10.75	2.25	3.9760	84.50	149.270	1.77	21.50	25.9	6.5
4	3.0	7.60	18.10	9.85	2.12	3.6300	65.70	113.580	1.78	18.00	25.9	7.1
5	2.5	6.51	17.01	9.56	1.61	2.0220	34.80	68.140	1.96	17.00	14.2	7.0
6	2.5	8.60	19.10	10.12	1.76	2.4440	46.70	82.430	1.77	19.05	17.7	7.2
7	2.5	10.05	20.55	10.50	1.79	2.5200	51.70	94.040	1.82	20.52	17.7	7.0
8	2.5	3.70	14.20	8.55	1.50	1.7670	25.10	47.520	1.90	14.10	14.2	8.0
9	1.5	4.61	15.11	9.04	.91	.6450	9.75	20.280	2.08	15.10	8.3	12.9
10	1.5	7.91	18.41	9.94	.97	.7382	13.60	29.170	2.14	18.40	5.9	8.0
11	1.5	10.41	20.91	10.60	1.05	.8590	17.97	36.020	2.00	20.90	5.9	6.9

The tabulation of the results of these different observations is given in Table II. The diameter of the jet was taken at its smallest part just before it struck the plate. This diameter was obtained by calipers, but is not very accurate.

Column 8 gives the area of the jet multiplied by its height. The factor of the heaviness of the water is left out because it is constant.

Column 9 gives the total pressure on the plate, ascertained from the individual readings, as explained in Table I. The method used in determining this total pressure is, of course, not very accurate, because the area of an annular strip at the outer edge of the jet is rather large comparatively; and, as the integration is by means of these strips, if we take one strip too many or one too little the value of the total pressure is considerably varied.

Column No. 10 is a constant obtained by dividing column No. 9 by column No. 8, and it confirms fairly closely the experiments of Bidone and of the two students at the University of Pennsylvania. The greatest pressure per unit of area is in the center of the jet, and by comparing column 11 with column 4 it is seen that the greatest pressure per unit of area is equivalent to the velocity head contained in the water.

Column 12 gives the total area over which the jet acts. Dividing this by the area of the jet, we obtain the quotients given in column 13, or the relation between the area of the jet and the area over which it acts on the plate.

In conclusion, we see that Mr. Church cannot apply equation (4) to the Pitot tube, (1) because the area over which the jet acts is not the same as the area of the jet; (2) because the greatest pressure on the plate never rises higher than the velocity head contained in the water. The readings of the column of water connected to the hole A, if we consider it as a Pitot tube, agree exactly with the formula $V = \sqrt{2gh}$.

EXPERIMENT 2.

Impingement of a Falling Jet of Water upon Nozzles of Different Forms.

There is such a variety of opinion as to the best form of nozzle or impact tube for use in a Pitot tube that it seemed to the writer advisable to experiment on tubes of different forms, with a view of obtaining some law regarding their variation.

Fig. 17 shows nozzles of four different shapes. Nozzle A is made canonically converging, according to descriptions given by Mr. Darcy. Nozzle B is Pitot's original form. It is made canonic-

ally diverging, or funnel-shaped. Nozzle C is the one Weisbach used in his experiments. Nozzle D is made according to the descriptions of Mr. Church, with the edges "plane and quite wide."

Object of the Experiment. The object of the experiment is (1) to determine the static head which nozzles of different forms will support when struck by a jet of known velocity; (2) to prove that velocity head is converted into static head according to the law $V = \sqrt{2gh}$.

The apparatus (Fig. 18) for obtaining the jet was the same as that used in Experiment 1. Two vertical glass tubes, $1\frac{7}{8}$ inches

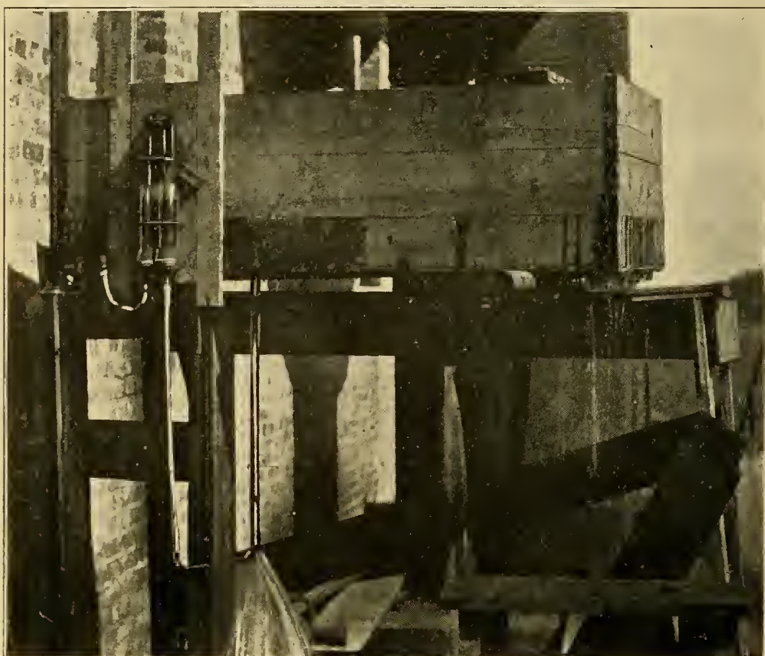

Fig. 18. Experiment with Nozzle A.

inside diameter and 8 inches long, are placed side by side on the box. The left-hand tube is connected directly, by $\frac{1}{4}$-inch gas piping and rubber tubing, with the interior of the box, while the other is connected with the nozzle by similar means. The large glass tubes are used in order to eliminate the effect of capillarity. The glass tube on the left (Fig. 18) gives the height of the water in the water box over the orifice, and the difference between this level and the point of the nozzle gives the total distance through which the water falls. The velocity of the water, then, at striking the nozzle is given by substituting this distance, in feet, in the formula

$V = \sqrt{2gh}$. Great care was used to get the nozzle exactly level and as near the center of the jet as practicable. The difference between the water level in the glass tube on the right and the end of the nozzle gives the distance through which the water rises, due to the impact on the end of the nozzle. The difference between the two water levels in the glass tubes gives the total loss of head necessary to convert the static head into velocity head, and to reconvert the velocity head into static head, as well as the loss by friction.

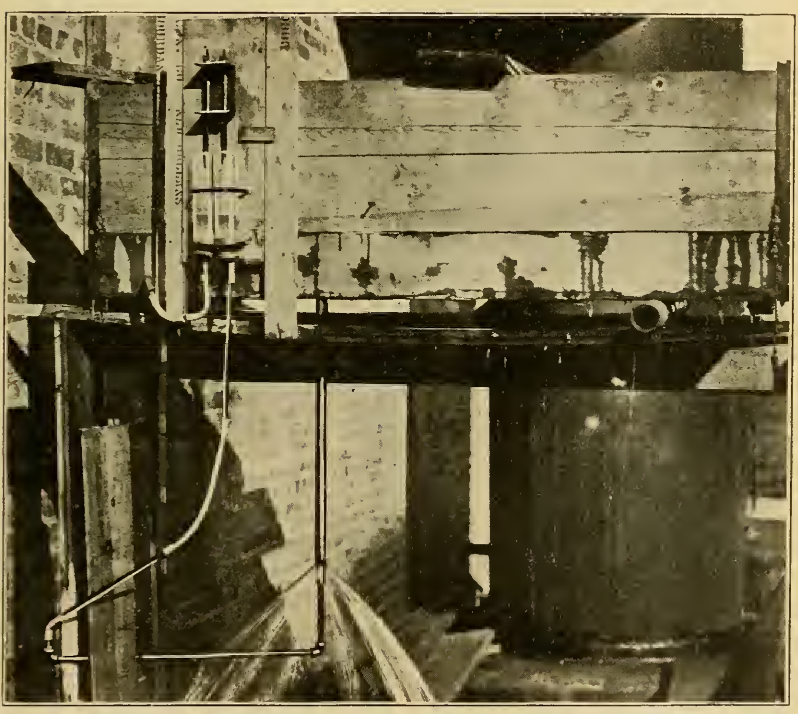

FIG. 19. EXPERIMENT WITH NOZZLE C.

Two hook gages, fastened to the end of a steel scale, were used to measure the difference between the water levels in the large tubes. The hooks were so arranged that they dipped into their respective tubes at the same time. By sliding the steel scale, which was graduated 1-64 inch, up and down, so that first the point of one hook came to its water surface and then the other, the difference between the water levels could be measured closely.

TABLE III.—Experiment 2.

Impingement of a Falling Jet of Water on Nozzles of Different Forms.

1	2	3	4	5	6	7	8	9	10		
Observation.	Nozzle.	Orifice. Inches.	Height of Orifice Above Nozzle. Inches.	Height of Water Level Over Orifice. Inches.	Total Distance Water Fell to Nozzle. Inches.	Height Water Rose in Tube Above Nozzle. Inches.	Per Cent. (7) of (6).	Velocity of Water at Striking the Nozzle from $V = \sqrt{2GH}$ Ft. per Sec.	For Pitot Tube $V = \phi\sqrt{2gh}$ $\phi = \frac{\sqrt{2gh(6)}}{\sqrt{2gh(7)}}$		Date of Observation, 1901.
1	B	1.5	32.750	5.5000	38.2500	38.1680	.9978	14.52	1.0022	Observations made with Steel Scale Graduated in $\frac{1}{64}$ s.	March 2.
2	A	1.5	29.370	5.5000	34.8700	34.7810	.9974	13.63	1.0026		"
3	A	1.5	29.370	8.5000	37.8700	37.7760	.9975	14.19	1.0025		"
4	A	1.5	29.370	3.2500	32.6200	32.5810	.9988	12.79	1.0012		"
5	A	1.5	29.370	3.2500	32.6200	32.5890	.9990	12.79	1.0010		"
6	C	1.5	32.250	3.5000	35.7500	35.6990	.9980	13.79	1.0020		"
7	C	1.5	32.250	9.7500	42.0000	41.9140	.9980	14.99	1.0020		"
8	D	1.5	32.370	4.5000	36.8700	36.8050	.9982	14.03	1.0018		"
9	D	1.5	32.370	8.5000	40.8700	40.7760	.9979	14.95	1.0021		"
10	D	1.5	15.500	5.5000	21.0000	20.9690	.9985	10.58	1.0015		"
11	D	1.5	15.500	9.0000	24.5000	24.4530	.9981	11.46	1.0019		"
12	C	1.5	15.500	9.0000	24.5000	24.4560	.9982	11.46	1.0018		"
13	C	1.5	15.500	3.8700	19.3700	19.3150	.9971	10.18	1.0029		"
14	B	1.5	15.750	3.8700	19.6200	19.5910	.9985	10.26	1.0015		"
15	B	1.5	15.750	8.0000	23.7500	23.7140	.9985	11.23	1.0015		"
16	A	1.5	12.250	8.0000	20.2500	20.2060	.9978	10.42	1.0022		"
17	A	1.5	12.250	8.0000	20.2500	20.1620	.9956	10.42	1.0044		"
18	A	1.5	12.250	3.7500	16.0000	15.9730	.9983	9.22	1.0017		"
19	A	1.5	12.250	3.7500	16.0000	15.9570	.9974	9.22	1.0026		"
20	C	1.5	18.750	8.3546	27.1046	27.0813	.9991	12.04	1.0009	Observations made with Micrometer.	March 13.
21	C	1.5	18.750	9.1580	27.9080	27.8786	.9989	12.20	1.0011		"
22	C	1.5	18.750	10.5036	29.2536	29.2073	.9984	12.50	1.0016		"
23	C	1.5	18.750	11.6318	30.3818	30.3318	.9983	12.75	1.0017		"
24	C	1.5	18.750	13.2228	31.9728	31.9048	.9981	13.08	1.0019		"
25	C	1.5	18.750	7.38.8	26.1378	26.0790	.9977	11.80	1.0023		"
26	C	1.5	18.750	6.1198	24.8698	24.8325	.9985	11.50	1.0015		"
27	C	1.5	18.750	5.2235	23.9735	23.9508	.9990	11.30	1.0010		"
28	B	1.5	5.312	6.2528	11.5648	11.5575	.9993	7.86	1.0007		March 21.
29	B	1.5	5.312	8.3828	13.6943	13.6890	.9996	8.56	1.0004		"
30	B	1.5	5.312	8.7455	14.0575	14.0490	.9993	8.67	1.0007		"
31	B	1.5	5.312	10.3238	15.6358	15.6248	.9993	9.15	1.0007		"
32	B	1.5	5.312	12.3132	17.6252	17.6127	.9993	9.72	1.0007		"
33	B	1.5	5.312	3.6447	8.9567	8.9560	.9999	6.92	1.0001		"
34	B	1.5	2.750	5.4233	8.1733	8.1677	.9993	6.66	1.0007		"
35	B	1.5	13.500	5.3700	18.8700	18.8470	.9988	10.08	1.0012		"
36	B	1.5	19.500	5.4472	24.9472	24.9203	.9988	11.50	1.0012		"
37	B	1.5	25.500	5.3072	30.8072	30.7638	.9986	12.78	1.0014		"
38	B	1.5	31.500	5.4405	36.9405	36.8765	.9980	14.08	1.0020		"
39	A	1.5	28.750	5.4007	34.1507	34.0943	.9983	13.50	1.0017		"
40	A	1.5	5.125	5.4302	10.5552	10.5488	.9994	7.52	1.0006		"

Observations 1 to 19, Table III, give the results as determined by this method. The results by this method of measurement varied too widely, and on another day of the experiment two micrometer screws were constructed (see Fig. 18). A hook was attached to each screw and dipped into one of the two glass tubes. In making an observation, (1) three readings were taken with the glass tubes connected as shown in Fig. 18, and (2) three readings were taken with the rubber tubes, which are connected to the bottom of the glasses, reversed. An average of these readings eliminated any error there might be in the zeros of the micrometers.

Observations 20 to 40 were made with the micrometers. These observations are the best that could be made. Nozzles of different

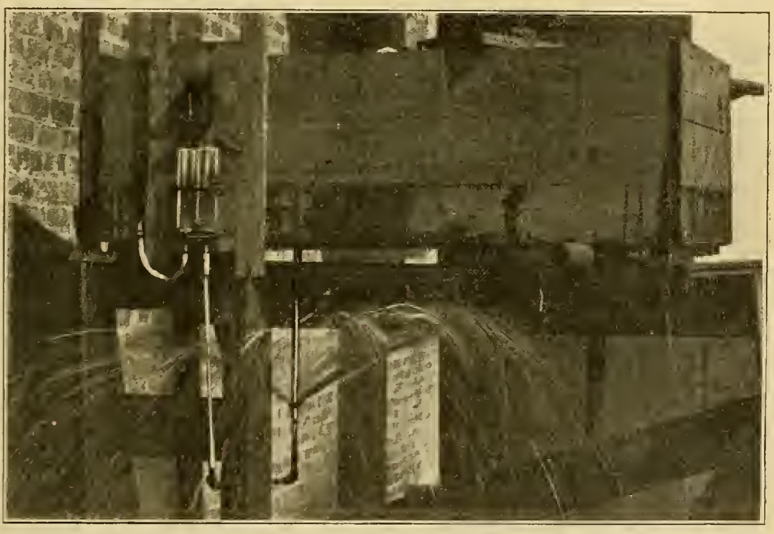

Fig. 20. Experiment with Nozzle B.

forms were used, and the jet was caused to strike each nozzle at different velocities. The difference between the two water levels was so slight that it was very hard to obtain any law of variation.

Column 10, Table III, gives the constant Φ as determined for the Pitot tube effect on these nozzles. The constant Φ contains all the losses. If we could eliminate the air friction and the friction at the orifice, its value would be unity.

Fig. 18 shows nozzle A in the jet. The jet binds closely around the nozzle and adheres to the pipe down to the elbow.

Fig. 19 shows the jet impinging on nozzle C, and observations in Table III were taken under this condition.

Fig. 20 shows a jet striking nozzle B. This jet is smaller than

the one used in the tabulated experiments, and was used in order to get a better photograph of the water as it leaves the nozzle. The two water levels can be seen in the glass tubes.

In Fig. 19 it is seen that the jet is deflected from its course by an angle $a = 45°$. If we substitute the value of the cosine of this angle in equation (3) (page 38) we have for the pressure on the nozzle (per unit of area according to Mr. Church)

$$P = F\gamma \frac{V^2}{g} (1 - \tfrac{1}{2}) = F\gamma \tfrac{1}{2} \frac{V^2}{g}$$

In Fig. 20 it is seen that the jet is turned from its course by an angle $a = 135°$. If we substitute the value of the cosine of this angle in equation (3) we have for the pressure on the nozzle,

$$P = F\gamma \frac{V^2}{g} (1 - (-\tfrac{1}{2})) = F\gamma \tfrac{3}{2} \frac{V^2}{2g}$$

But by experiment the pressure per unit of area at the point of the nozzle is constant and equal to the velocity head contained in the water, no matter at what angle the jet may be deflected. Therefore, equation (3) does not apply to the pressure per unit of area, but to the total pressure necessary to turn the jet.

In Fig. 18 the jet binds closely to the nozzle, but the stream lines may leave the point of the nozzle at some angle which has not been determined.

Conclusions. From the results of Table III we see (1) that velocity head is converted into static head according to the law $V = \sqrt{2gh}$; (2) that no matter at what angle the water leaves the nozzle, the greatest pressure per unit of area never rises above the velocity head contained in the water.

Stream Lines and Velocities of a Jet Impinging on a Flat Plate.

It is claimed by Mr. Kent that the formula is $V = \sqrt{gh}$, and the reason that the calibration of tubes never shows quite so high a result is that a cone of still water may exist at the center of the nozzle of the tube and that the water sliding down the sides of this cone fails to exert its full force upon it. An experiment was made to determine whether this cone existed.

A small jet was caused to impinge on nozzle D (Fig. 17), of such a diameter that the jet was turned at right angles as it left the plate. The hole in the center of the nozzle was connected by piping and rubber tubes to a funnel placed above the level of the water in the water box. A blue solution of metalyne was poured gently into the funnel. The solution came out quietly through the hole in the nozzle in the center of the jet. If a cone of quiet water should exist at that point, the blue solution would force its way in and gradually displace the clear water, leaving a blue cone, which could

be seen. But the moment the bluing came to the surface of the nozzle it disappeared along the surface as fast as it was supplied. This, I submit, proves that no such cone exists.

Another experiment (Fig. 21) was made to determine the stream lines throughout the jet. In this experiment a 2-inch jet was allowed to impinge upon a large flat glass plate. An $\frac{1}{8}$-inch tube was connected by rubber tubing to the funnel, and the same solution of metalyne used. By holding the small tube in the jet as it came through the orifice, and pouring the solution of metalyne in the funnel, a small blue line could be plainly seen running down through the jet onto the plate and running off at right angles.

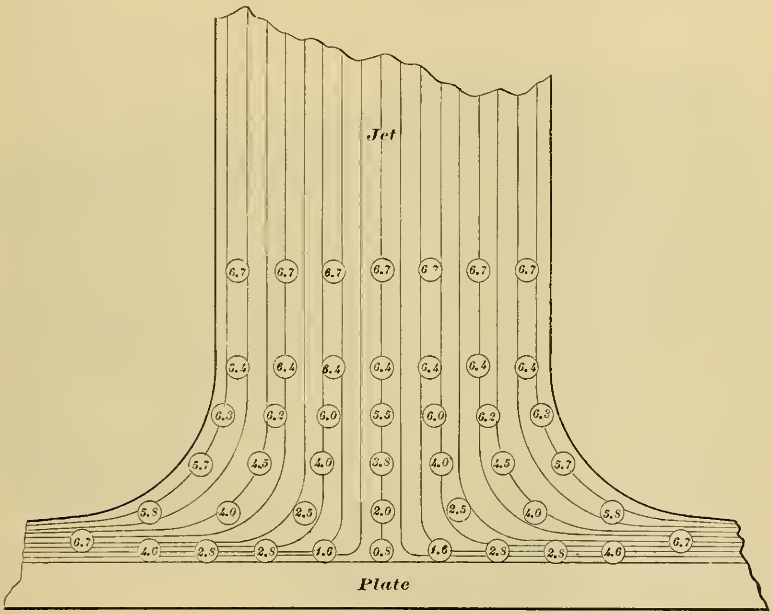

FIG. 21. STREAM LINES AND VELOCITIES OF A JET IMPINGING ON A PLATE.

When the small tube was held in the center of the jet, the blue line seemed to run to the surface of the plate and then turn suddenly at right angles along the surface. By moving the small tube along a diameter of the jet, the stream lines could be traced, as shown in Fig. 21. The numbers in the small circles (Fig. 21) give the velocities in feet per second at that point of the jet. These velocities were obtained by the means of a very small Pitot tube. The point readings of the Pitot tube always remain near the water level in the box, the static part of the tube varying as the velocities. In other words, the sum of the static and velocity heads is always equal to the distance through which the water falls.

It will be noticed that the velocity of the jet during its change of direction is less than it is either before reaching the changing point or after leaving it. The changing point of the jet seems to act like a reservoir under pressure, being supplied from the jet above and discharging along the surface of the plate. The stream lines show very clearly that no cone exists at the center of the jet.

The stream line in the center of Fig. 21, together with the velocities inclosed in the little circles along that line, show very prettily the conversion of velocity head into static head. For instance, at the top of the line, where the velocity is 6.7, the static head is zero. From that point to the plate the velocity head gradually decreases, being replaced exactly by the static head, as the reading of the Pitot tube shows.

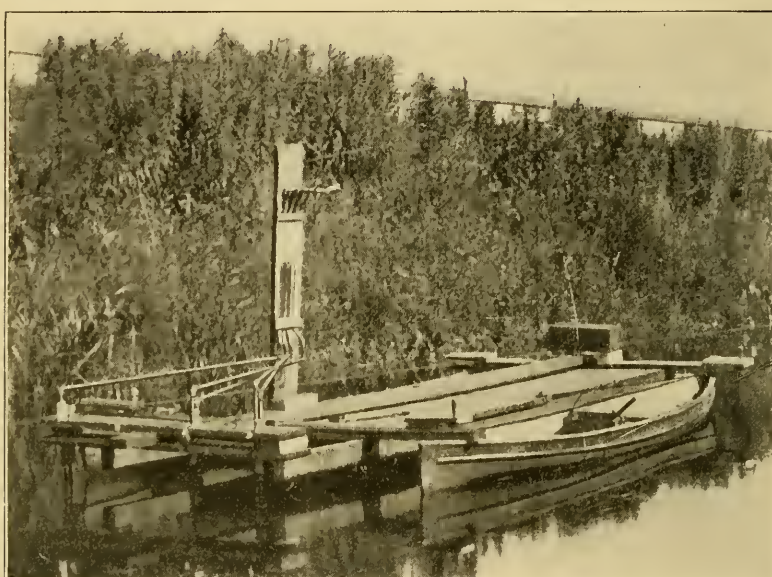

Fig. 22.

EXPERIMENT 3.

Calibration of Nozzles.

This experiment (see Fig. 22) was made to test the nozzles under actual working condition. The tubes were moved through still water at a known velocity, and the constant of the tubes determined in this way. This calibration was made in the Jourdan Avenue Canal, which is blanked off at one end; it consequently has very little current, and offers exceptional conditions for a calibration of this kind. For a course, a No. 8 galvanized iron wire was stretched 600 feet just above the surface of the water. A point was marked on the wire 150 feet from each end. Stakes driven at these marks were used as starting and stopping points, and left

between them a clear measured course of 300 feet; 150 feet on each end was used to get a start before crossing the line and to check the headway after crossing the last line. Two small boats were placed side by side, with their center lines 6 feet apart. A decking was built over them, forming a catamaran. One side of the catamaran was fastened to the wire with staples. A tow line running to the shore was used to haul the boat along the canal at any desired velocity. On the first day of the experiment nozzles A, B, C and D, Fig. 17, were connected by gas pipes and glass tubings to the same vertical scale, graduated to .01 foot. The tubes and scale were fastened to a long 2 x 4-inch wooden piece, and could be

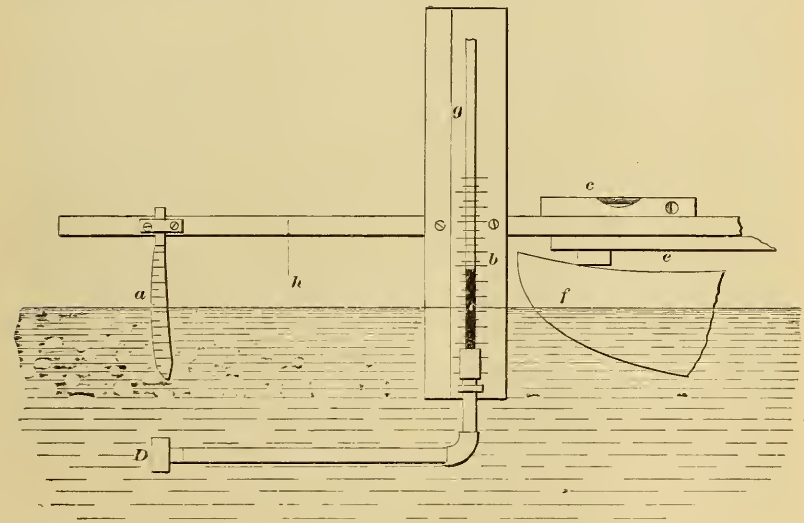

FIG. 23.

changed from one end of the boat to the other at will (see Fig. 23). The nozzles were placed about 24 inches in front of the bow of the boat, 12 inches from each other, and submerged 18 inches. When in position for reading, part of the scale and of the glass tubes was under the water. To get the static head of water, as referred to the scale, a butcher knife, *a,* with tne scale etched to .01 foot, was placed between the scale and the end of the nozzle at h (Fig. 23). In making a reading, a spirit level was placed on the boat, and the observers so arranged themselves that the boat was perfectly level. Three observers were necessary; one to lay on the catamaran and put his head over within a few inches of the water and read the two scales; another recorded these readings as rapidly as read; the third took the time with a stop-watch, reading in fifths of a second in going the 300 feet. The greatest care was taken to get the nozzles exactly in the line of motion. When the boat was hauled forward, the water rose in the glass tubes on the scale, and the four heights

could be read. But no matter at what velocity the boat was hauled, the four water levels from the different nozzles came to exactly the same height. This proves that the form of nozzle for a Pitot tube makes no difference so long as it is a surface of revolution with its axis exactly in the line of motion.

On the first day of this test sixteen observations were made, and the value of Φ in $V = \Phi \sqrt{2gh}$ was found to be 1.087. This result is considerably off, and the error was caused by the knife *a* (Fig. 23) being placed at *h* (Fig. 23); that is, not directly above the nozzles. The water surface at *h* is rising to meet the bow of the boat, and gives a false reading on the knife.

On the second day of the experiment—some two weeks later—nozzle D was connected as shown in Fig. 23. The knife scale, *a*, was placed directly above the nozzle. In making a reading, the spirit level was placed as shown in Fig. 23, and the observers arranged themselves so that the boat was level. By watching the spirit level, in making a reading, the boat was kept level at all times. This was necessary in order that the zero readings of the two scales should remain the same. Before each observation the reading of the two scales was taken with everything perfectly quiet. The boat was then hauled forward with a constant velocity. The observer read the water levels on the two scales, one after the other, as rapidly as possible. The recorder made a note of these readings. An average of these readings was taken for the value of *h* in an observation. Table IV gives the result of the observations of the day's test.

TABLE IV.—Calibration of Nozzle D.

1	2	3	4	5	6	7	8	9	10
Observation.	Reading of Tube Scale.	Reading of Static Scale referred to Tube Scale.	Difference (2)-(3) or h in $V = \sqrt{2gh}$	Velocity from $V = \sqrt{2gh}$	Time.	Distance.	Velocity.	Direction.	$\phi = \frac{\text{True Velocity}}{\sqrt{2gh}}$
	Feet.	Feet.	Feet.	Feet per Sec.	Secs.	Feet.	Feet per Sec.		ϕ
1	.605	.290	.315	4.50	66.0	300	4.55	Up	1.010
2	.667	.308	.359	4.80	63.4	300	4.73	Down	.987
3	.744	.325	.419	5.19	56.8	300	5.28	Up	1.018
4	.737	.346	.391	5.01	58.4	300	5.14	Down	1.027 ?
5	.556	.290	.266	4.13	71.8	300	4.18	Up	1.012
6	.545	.313	.232	3.86	79.2	300	3.79	Down	.982
7	1.014	.318	.696	6.69	44.4	300	6.76	Up	1.010
8	.950	.372	.578	6.09	49.4	300	6.07	Down	.997
								Average,	1.0053

Column 9, Table IV, gives the direction of the observations determining the values of Φ in column 10, showing that there was a slight current in the canal. But by taking a reading up the canal, immediately followed by a reading down the canal, the error due to this current was eliminated. Observation No. 4 does not give the correct reading, because the boat was not exactly level and, as shown by the reading on the static scale, the knife was too deep in the water. But this observation has not been discarded. In fact, no observation has been discarded throughout this series of tests. The value of Φ for the eight observations is 1.0053 for $V = \Phi\sqrt{2gh}$. The calibration of nozzle D applies to nozzles A, B and C, because on the first day of the test they were hauled at different velocities and they always gave exactly the same reading of h. The highest velocity obtainable by hauling the boat through the water was about 6 feet per second. Nozzles A, B, C and D, Fig. 17, were afterward all connected to the same scale by pipes and inserted in the discharge pipe of a centrifugal pump. The velocities of the water through the pipe were varied from 8 to 15 feet per second, but the reading of h on the four different tubes was always exactly the same.

In conclusion, we see from this experiment that velocity head is converted into static head in accordance with the law $V = \sqrt{2gh}$, and that the correct formula for the theoretical Pitot tube is $V = \sqrt{2gh}$ without the introduction of any constant.

EXPERIMENT 4.

Calibration of Pitot Tubes.

In this experiment four different tubes (Fig. 24) were calibrated under exactly the same conditions. Tubes M and N are designed by the writer. Tube M is made of gas pipe, having nozzle B fastened on the end of one of the pipes for the impact tube. Nozzle b is made round, long and sharp, with a hole at right angles to the length running through the nozzle, the middle of the hole being connected to the gas pipe, as shown by the dotted lines.

Tube N is made in the same manner, except that it is entirely of gas pipe. Nozzle e is an ordinary $\frac{1}{4}$-inch gas pipe with its end filed square. Nozzle f is a $\frac{1}{4}$-inch gas pipe drawn to a point, and a hole is drilled through it at right angles to its length.

The hatchet-shaped tube is one designed by Professor Gregory. It is made of brass, nicely polished.

The Tulane tube is the one that was used in the test, and is the one under criticism by Mr. Kent. It is made of two $\frac{1}{4}$-inch tees fastened together by an iron plug. On the end of one of them is

fastened a nozzle, *g*, and through the other are drilled holes which are intended to give the static pressure. Unfortunately, the tee k was broken after the calibration of last year, and had to be replaced by a slightly larger one. This causes a slight difference in the value of its constant Φ. The four tubes were fastened in front of the boat at the same depth below the water, and 14 inches apart. The tubes were all connected to glass tubes placed on the same vertical scale. All the glass tubes were connected together at the top to a common vacuum chamber. The air was exhausted from this chamber, and the water levels thus drawn up on the scale. When the boat was hauled forward at any velocity, the readings of the impact tubes of the four different Pitot tubes were always

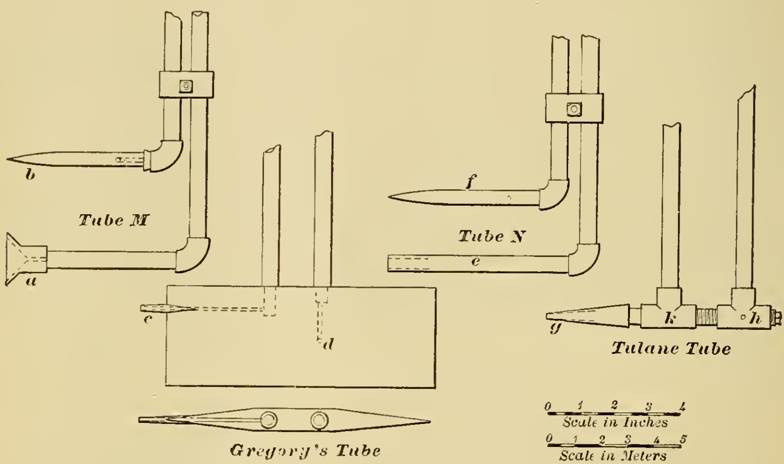

FIG. 24.

exactly the same, but the static readings of the different tubes were always different, showing that there was a suction action of greater or less degree on some of the tubes.

The same method of observation was used in this experiment as was used in Experiment 3. An observer read the different water levels on the scale, which were recorded as rapidly as read. The timekeeper took the time by the stop-watch in going the 300 feet. Ten readings were usually made in one observation, and the average of these readings gave the different values of h for the different tubes in an observation. Table V gives the result of this experiment.

TABLE V.—CALIBRATION OF PITOT TUBES.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
	All Readings on Same Scale.					Point Reading Minus Static Reading, or, h.				Velocity by Tubes from $V = \sqrt{2gh}$								For Pitot tube $V = \phi\sqrt{2gh}$; $\phi = \frac{\text{True Velocity}}{\text{Pitot Tube Velocity}}$.			
Observation.	Point Readings of all Tubes.	Static Reading of Tube M.	Static Reading of Gregory's Tube.	Static Reading of Tube N.	Static Reading of Tulane Tube.	Tube M.	Gregory's Tube.	Tube N.	Tulane Tube.	Tube M.	Gregory's Tube.	Tube N.	Tulane Tube.	Time.	Distance.	Velocity.	Direction.	Tube M.	Gregory's Tube.	Tube N.	Tulane Tube.
	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Ft. per Sec.	—	—	—	Seconds.	Feet.	Ft. per Sec.	—	ϕ	ϕ'	ϕ''	ϕ'''
1	.9286	.6086	.5828	.5857	.4771	.3200	.3468	.3429	.4515	4.54	4.72	4.69	5.39	64.0	300	4.59	Down	1.0110	.9740	.980	.853
2	.9866	.5633	.5416	.5783	.4633	.4233	.4450	.4083	.5233	5.22	5.35	5.13	5.80	57.4	300	5.23	Down	1.0020	.9780	1.020	.902
3	.9086	.6428	.6100	.6171	.5114	.2658	.2986	.2915	.3972	4.13	4.38	4.33	5.05	73.0	300	4.12	Up	.9980	.9400	.950	.816
4	.9112	.6437	.6187	.6212	.5325	.2675	.2925	.2900	.3787	4.14	4.34	4.32	4.93	74.0	300	4.06	Up	.9810	.9360	.940	.824
5	.9816	.5633	.5400	.5683	.4416	.4183	.4416	.4133	.5400	5.19	5.32	5.15	5.89	58.4	300	5.14	Up	.9910	.9670	.998	.874
6	.9483	.5916	.5614	.5950	.4850	.3567	.3869	.3633	.4633	4.79	4.99	4.83	5.46	63.4	300	4.74	Up	.9900	.9500	.982	.870
7	.9471	.5843	.5628	.5857	.4671	.3628	.3843	.3614	.4800	4.83	4.97	4.82	5.55	62.4	300	4.82	Up	.9980	.9700	1.000	.869
8	.8416	.6114	.5733	.5900	.5166	.2300	.2683	.2516	.3250	3.84	4.16	4.01	4.57	73.8	300	4.07	Down	1.0600	.9770	1.010	.889
9	.8000	.6471	.6286	.6471	.6128	.1529	.1714	.1529	.1872	3.13	3.32	3.13	3.47	92.8	300	3.23	Down	1.0300	.9740	1.030	.930
10	1.0325	.5700	.5300	.5775	.3725	.4625	.5025	.4550	.6600	5.45	5.69	5.41	6.52	54.4	300	5.52	Down	1.0100	.9700	1.020	.848
																	Average,	1.0071	.9636	.993	.867
11	.8457	.6657	.6343	.6600	.6114	.1800	.2114	.1857	.2343	3.40	3.69	3.45	3.88	84.0	300	3.57	Down	1.0500	.9670	1.035	.920
12	.8616	.6700	.6650	.6816	.6416	.1916	.1966	.1800	.2200	3.51	3.56	3.40	3.76	85.0	300	3.53	Down	1.0050	.9920	1.040	.940

Observations $\left\{\begin{matrix}11\\12\end{matrix}\right\}$ made with tubes turned ten degrees to the $\left\{\begin{matrix}\text{right}\\\text{left}\end{matrix}\right\}$ of the direction of motion.

The values of Φ for the tubes M and N are within .7 per cent. of unity. For Professor Gregory's tube, Φ = .9636, showing a slight suction action at the static part of the tube. The value of Φ for the Tulane tube is .867, showing a suction action of .33 $\frac{V^2}{2g}$.

Observations 11 and 12 were made with all the tubes turned 10° to the right and left of the direction of motion. These observations are to determine what effect there is when the tubes are not exactly in line.

In conclusion, we see that the theoretical formula for all Pitot tubes is $H = \frac{V^2}{2g}$, but in most practical tubes the value of H is increased by a suction action at the static attachment; and so, when we take this action into account, we have for the value of H,

$$H = \frac{V^2}{2g} + C\frac{V^2}{2g}, \text{ or simply}$$

$$V = \Phi\sqrt{2gh}$$

$$\text{where } \Phi = \sqrt{\frac{1}{1+C}}$$

EXPERIMENT 5.

Comparison of Velocities made with the Pitot Tube having the Oil Gage Attached, and with the Price Current Meter.

The Pitot tube, as ordinarily used, will not give accurate readings for low velocities, because the difference of the water levels is very slight, and it therefore cannot be read accurately.

The writer has devised a method for exaggerating the difference between the water levels for the same pressure at the point of the nozzle. The invention consists in substituting oil for air in the Pitot tube gage. When the pressure at the point of the tube is .1 of a foot of water, corresponding to a velocity of 2.53 feet per second, the reading of the difference of the two water levels on the scale, with air above them, is .1 of a foot. When the pressure at the point remains the same and oil is substituted for air in the gage, the difference between the two water levels increases until the difference betwen the weights of the column of oil and the column of water, due to their different specific gravities, is equal to the pressure at the point.

Let P = the pressure at the point of the nozzle in feet of water.

Let L = the difference between the two water levels in feet.

Let y = the specific gravity of the oil. Then P = L (1-y).

Let us suppose, for example, that oil of specific gravity .9 be substituted for the air in the gage, then P = .1 L, or the scale reading is multiplied ten times.

TABLE VI.

COMPARISON OF READINGS OF THE PITOT TUBE WITH OIL GAGE ATTACHED AND THE PRICE CURRENT METER.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Observation.	Scale Reading of Pitot Tube: Point.	Scale Reading of Pitot Tube: Static.	Difference (2) - (3).	h in feet of Water (4) Mult. by 0.078.	Revolutions of Price Current Meter.	Revolutions per Second.	Distance.	Time.	True Velocity = $\frac{D}{T}$	Velocity by Pitot Tube.	Velocity by Price Current Meter.	$\frac{\text{True Vel.}}{\text{P. T. Vel.}}$	$\frac{\text{True Vel.}}{\text{P. C. M. Vel.}}$	Direction.
	Oil Gage Readings. Feet.	Feet.	Feet.	Feet.	Total.	—	Feet.	Secs.	Feet Per Sec.	Feet Per Sec.	Feet Per Sec.	—	—	—
1	2.7081	1.6137	1.1944	.09317	95	.7565	300	125.6	2.388	2.446	2.435	.977	.982	Up
2	2.7293	1.5921	1.1372	.08860	94	.7550	300	124.5	2.410	2.385	2.430	1.010	.992	Down
3	2.5215	1.8215	.7000	.05460	93	.5980	300	155.8	1.928	1.873	1.945	1.028	.991	Up
4	2 5124	1.8333	.6791	.05290	95	.5820	300	163.4	1.837	1.844	1.895	.996	.969	Down
5	2.4185	1.9445	.4740	.03690	93	.4800	300	193.8	1.550	1.542	1.578	1.005	.982	Up
6	2.4228	1.9390	.4838	.03768	91	.4700	300	193.8	1.550	1.556	1.550	.997	1.000	Down
7	2.3098	2.0746	.2352	.01832	93	.3330	300	279.4	1.075	1.085	1.125	.992	.956	Up
8	2.3085	2.0765	.2320	.01808	91	.3301	300	275.8	1.088	1.075	1.115	1.012	.976	Down
9	2.2550	2.1437	.1113	.00868	89	.2137	300	417.0	.719	.747	.755	.963	.953	Up
10	2.2588	2.1314	.1274	.00994	86	.2318	300	371.2	.808	.800	.810	1.010	.998	Down
11	2.2267	2.1797	.0470	.00366	88	.1295	300	680.2	.442	.485	.495	.910	.893	Up
12	2.2215	2.1888	.0327	.00255	78	.1013	300	770.0	.390	.405	.407	.963	.958	Down
13	2.3053	2.0800	.2253	.01758	91	.3159	300	288.2	1.042	1.063	1.070	.980	.974	Up
14	2.3094	2.0609	.2485	.01939	91	.3410	300	267.6	1.122	1.118	1.148	1.003	.978	Down
15	2.4033	1.9554	.4479	.03492	91	.4560	300	199.4	1.504	1.498	1.505	1.004	.998	Up
16	2.4071	1.9487	.4584	.03578	91	.4470	300	203.6	1.475	1.514	1.475	.979	1.000	Down
17	2.5011	1.8326	.6685	.05208	94	.5725	300	164 2	1.828	1.830	1.865	.999	.981	Up
18	2.5080	1.8155	.6925	.05400	92	.5840	300	157.6	1.904	1.863	1.900	1.022	1.002	Down
19	2.6086	1.7000	.9086	.07080	94	.6640	300	141.6	2.120	2.134	2.148	.994	.987	Up
20	2.6189	1.6805	9384	.07320	93	.6810	300	136.6	2.198	2.168	2.200	1.012	1.000	Down
21	2.7105	1.5894	1.1211	.08750	96	.7400	300	129.6	2.317	2.372	2.383	.976	.970	Up
22	2.7095	1.5945	1.1150	.08700	92	.7260	300	126.2	2.378	2.365	2.340	1.005	1.015	Down
23	2.8211	1.4805	1.3406	.10450	96	.8070	300	119.0	2.502	2.593	2.592	.973	.973	Up
24	2.8178	1.4623	1.3555	.10580	93	.8240	300	112.8	2.660	2.608	2.645	1.020	1.005	Down
25	2.9033	1.3713	1.5320	.11940	97	.8300	300	110.8	2.710	2 770	2.665	.979	1.018	Up
26	2.9150	1.3731	1.5119	.12040	94	.8870	300	106.0	2.830	2.783	2.840	1.018	.997	Down

In the experiment linseed oil of .922 specific gravity was used. Consequently the scale readings were multiplied by .078 for reduction to difference of water levels in feet of water. The specific gravity of the oil was determined at the same temperature at which it was used in the experiment.

The Pitot tube, with oil gage attached, and Price current meter were placed on the catamaran. The catamaran was hauled through still water at different known velocities, and the readings of the velocities, as given by the Pitot tube and by the Price current meter, were compared with the true velocity. The same method of observation was used in this experiment as in Experiment 3. The Pitot tube used was tube M (Fig. 24), and its constant was taken as unity.

The Price current meter was rated in October, 1900. Its rating is $y = ax + b$. Where y is the velocity in feet per second, x is the number of revolutions of the meter wheel per second, and a and b are the constants of the instrument. The value of a was determined to be $a = 3.0968$. The value of b, $b = .0936$.

The rating was very carefully made over a 500-foot course, and there is every reason to believe that it is accurate. The current meter and the Pitot tube were placed 2 feet in front of the bow of the catamaran and submerged equal depths below the surface of the water. After each observation, the direction of the boat was reversed, and the next observation taken in going back over the course. This eliminated any error due to a current in the canal. Table VI gives the results of these observations.

Column 4 gives the average difference between the water levels on the oil gage. These differences are averages of about fifteen readings.

Column 5 gives the equivalent of column 4 in feet of water. The numbers in column 5 substituted in the formula $V = \sqrt{2gh}$ give the velocities recorded in column 11.

Columns 13 and 14 give the percentages of error of the Pitot tube and of the current meter. By an inspection of these two columns it is seen that the Pitot tube, with the oil gage attached, is as accurate on low velocities as the current meter, and offers the advantage of having no time element.

The writer wishes to express his indebtedness to Mr. B. Shall for the splendid photographs taken by him and for his assistance with the Price current meter. The writer is also indebted to Mr. H. Rummel, engineer of Jourdan Avenue station, and to his efficient force, for many courtesies extended.

DISCUSSION.

MR. GEORGE H. FENKELL.*—The experiments conducted and described by the author are extremely interesting and instructive, for it is by means of such as these that the laws governing the flow of water will be better understood.

Table VI shows that the "Pitot tube, with the oil gage attached, is as accurate on low velocities as the current meter," etc. This depends upon circumstances. In a wide and deep-flowing river the current meter offers advantages which the Pitot tube does not possess, although this does not imply that the latter cannot be used; for in April, 1898, a Pitot tube connected to the oil differential gage, described in the Proceedings of the American Society of Civil Engineers for May, 1901 (Experiments at Detroit, Mich., on the Effect of Curvature Upon the Flow of Water in Pipes, page 382) was used for taking velocity measurements at various depths in the Detroit River near the Detroit Water Works pumping station. The oil gages had been constructed in 1897, and were used to a limited extent in determining velocities in pipes under pressure.

In many places the Pitot tube offers advantages. To cite one investigation that the writer conducted: It was necessary to determine the quantity of water used by a water wheel working under a very low head. Floats could not be used, and weir would cause back-water on the wheel; but excellent results were obtained with a Pitot tube. A temporary shute was constructed in the tail race, 16 feet long and 15 feet wide, through which the water passed at a high velocity and from 10 to 15 inches deep. A sled, sliding on a carefully leveled track formed of 6 x 12-inch timbers, carried the tube, and readings were taken at various depths and positions.

Although almost any form of tube, if properly rated, can be used in open streams, some work better than others; for, if improperly constructed, when readings are taken with the point near the surface, the eddy caused by the tube will allow air to follow down the downstream side of the tube and reach the side or static opening, thereby destroying the partial vacuum maintained in the gage by admitting air in the tube. It would seem to the writer that this would be true with the Tulane tube, Fig. 24.

No matter what tube is used, the water must be free from floating moss and weeds, and if the tube openings are small, trouble will be experienced in any water carrying large quantities of mud or silt.

**Member Detroit Engineering Society.*

Mr. Clarence W. Hubbell.*—The experiments described are of more than usual interest to the writer, who has, during the last four years, used and rated a number of Pitot tubes of various forms and designs in his connection with the work of the engineering department of the Detroit Water Works; first as chief draftsman, and since October, 1898, as civil engineer in charge. A paper published in the May Proceedings of the American Society of Civil Engineers, and still open for discussion, describes original investigations in which Pitot tubes and oil gages were used. The writer does not feel it necessary to enter into a description or details of work there fully given, but will merely call attention to a few points which the present paper brings out.

First, from a personal experience with the difficulties to be overcome in conducting such investigations, the writer especially appreciates the amount of painstaking labor involved and careful observations and reductions necessary to reach the published results and conclusions presented by the author. All experimental data must be closely scrutinized, and the results accepted only after a careful analysis, and even then with both caution and judgment. The well-worn axiom still stands, however, that "an ounce of experimental truth is worth more than a pound of theoretical deduction." Along this line the experimental determination of the action of a jet impinging on a plane surface apparently shows, in a very interesting manner, both the truth and fallacy of existing theories.

In describing the third experiment, the author states that "the form of nozzle for Pitot tube makes no difference, so long as it is a surface of revolution and its axis exactly in the line of motion." It appears to the writer, however, that the results of the first experiment, taken in the light of those which follow, would authorize a somewhat broader statement, and that the form of nozzle need not necessarily be a surface of revolution,—a result apparently substantiated by experiments with tubes of the knife-edge type, with which the writer is familiar. The point is well taken that each individual tube must be standardized, and that the opening giving the static pressure causes the principal variation in the rating of different tubes.

In the fall of 1897, the writer used an oil gage with a Pitot tube in determining the flow through a 42-inch cast iron main under pressure, and experimented with various oils of different specific gravity, common kerosene giving the best results.

Numerous data with reference to oil gages, their calibration and use will be found in the paper above referred to. The time

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required for an oil gage to reach equilibrium is, however, much greater than for the same gage filled with air and water. This is especially true when a heavy oil is used and the tube openings are small. Where there are a large number of points to be observed in a cross-section, requiring the frequent moving of the point of the tube, the extra time required at each position becomes a serious objection.

Mr. Gardner S. Williams.*—This paper is one of particular interest to the writer, as it throws much additional light upon phenomena observed by him in connection with an investigation† to which he has devoted considerable attention for several years. The experiments of the writer and his co-laborers confirm the explanation of the author of the reason why a Pitot tube frequently indicates a higher velocity than actually exists when the theory that $V^2 = 2gh$ or $h = \frac{V^2}{2g}$ is applied to the observations. If more evidence upon the effect of water flowing past the pressure openings of such instruments is desired, attention is called to the head observed by means of a 1-inch pipe laid transversely across an open channel and 8 inches above the bottom, with $\frac{1}{8}$-inch diameter perforations on its under side, as compared with that observed upon a pipe having a similar series of perforations laid transversely in the bottom of the channel, the openings being flush with and at right angles thereto, as represented in columns 5 and 6 of Table No. 8, pages 326 and 327, Transactions of the American Society of Civil Engineers, Vol. XLIV. That orifices, situated similarly to those in the upper transverse pipe, do not give a head in open channels corresponding to the height of the water surface above them when placed in a current has been observed by the writer many times, the fact having been first brought to his attention by Mr. Hiram F. Mills, C. E., of Lowell, Mass. It has always seemed to the writer that a more careful reading of Weisbach bv those authorities who have adopted the impact theory for the Pitot tube would have shown that the case of the limited stream impinging upon an unlimited surface was quite a different matter from the unlimited stream impinging upon a limited surface, and it requires no very great stretch of imagination to conceive that the Pitot tube velocity opening conforms to the latter and not the former condition. In view of this, the writer early decided to cast his lot with Darcy, Bazin, Mills and Freeman, and adopted the formula $h = \frac{V^2}{2g}$ for

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†See Proc. Am. Soc. C. E., May, 1901. "Experiments at Detroit, Mich., on the Effect of Curvature, etc."

the reduction of Pitot tube observations. But although the experiments with which the writer has been connected have convinced him of the correctness of his conclusions, he is none the less pleased to see the question worked out in the very conclusive and accurate manner in which it is presented by the author, and he ventures the prediction that when it is shown, as it can be, that the observed results will be the same, whether one foot or one mile of connecting hose intervenes between the orifice and the tube gage, it will be rather difficult to controvert the author's deductions with a claim of frictional losses in the apparatus.

The conclusion drawn from these experiments as to the effect of the form of the velocity or point ajutage upon its coefficient,—*i.e.,* that for an orifice bounded by a surface of revolution,—in a plane at right angles to the direction of motion, the coefficient is sensibly the same, whatever the form or extent of the exterior walls, is also of especial interest. This view is that generally accepted by those most familiar with the instrument, and follows from the theoretical discussion based upon straight line flow in the water, but the experiments of the author do show a very slight variation of coefficient for the tubes as experimented upon in the jets, which may, however, be easily accounted for by small errors in observation or position of the instrument. From the writer's experience, he has been inclined to the view that in flowing water the coefficient of the velocity opening might be modified slightly by the form of the surrounding walls, and the experiments discussed upon pages 380 and 381 of the paper already referred to* seem to bear out this conclusion, although it is to be admitted that the differences there exhibited, except in one case, are not so great but that they might be accounted for by slight changes of condition within the pipe or in the position of the point of the instrument; nevertheless the coincidence of similar points, as those of tubes Nos. 3 and 6 and of tubes C and E as exhibited in the equations on page 343 and on Plate XII of that paper, would seem to favor the other contention. The points Nos. 3 and 6 were the only ones strictly conforming to the author's specification, as the others were circular orifices in knife edges and not in surfaces of revolution. It appears quite clear, however, that a point of the type of tube D of the writer, in which the knife edge projects beyond the center of the orifice, will have a higher coefficient than will one in which all sides of the orifice are in a plane. The experiments of the writer indicate, as is also shown by the author's work, that the

*Proc. Am. Soc. C. E., May, 1901.

coefficient of any given instrument is practically a constant for both point and pressure openings for all velocities so long as the conditions of flow do not change; but the same coefficient that holds for the conditions of normal flow does not hold for either point or pressure opening when the instrument is brought within the influence of a contraction in a pipe.

So far as the experiments go with which the writer is familiar, as well as those in the paper under discussion, they seem to indicate that the coefficient of a Pitot tube obtained by dragging the instrument through still water is not applicable to the apparatus when used in running water. For how much of this difference of coefficient the two parts of the apparatus are severally responsible the writer is unable to state, but his opinion is that the major part is to be accounted for at the pressure openings.

The oil differential gage described by the author was also invented, in 1897, by the writer and his associates at Detroit, Mich., and used by them to measure Pitot tube heads and losses of head in pipes in 1898; and instruments of that type, together with the results obtained by them, were exhibited to various members of the American Society of Civil Engineers at its annual convention at Detroit in July of that year, and, among others, were shown to a gentleman from New Orleans, connected with the drainage work, who received permission to communicate the device to the subordinates on that work. So far as the writer is aware, this was the first application of the device to the measurement of differences of head in water, although he has since learned of the use of a similar instrument to measure losses of head in flowing gases. The author's reduction of the gage observations is slightly in error, for, as determined by a long series of experiments, the coefficient of such a gage, computed from the specific gravities of the liquids, in the case of oil and water does not agree with that obtained by a comparison directly with two water columns. For kerosene, the true coefficient of multiplication has been found to be about 4 to 5 per cent., and for sperm oil 10 to 12 per cent. in excess of those computed from the specific gravities. That is to say, the instrument actually magnifies the difference of head more than is indicated by the author's computation. It is also very essential when using this gage to take account of the temperature, which has a very marked influence upon the coefficient, though the change of specific gravities is small.

This increased multiplying effect seems to be due to the adhesion of the oil to the glass, which is equivalent to an added weight of material when motion of the fluids begins. The fact

that thus far no such phenomena have been observed with mercury differential gages where the liquid has no affinity for the glass supports this explanation. Experiments upon tubes of different diameters would probably demonstrate its error or correctness, but the fact remains, however it be explained.

In the author's experiments the error in velocity would not be very great, as it is reduced in taking the square root of the observed quantity. The effect would be, when it is corrected, to increase the velocity obtained by the tube, and therefore to bring its coefficient down more nearly to that of the current meter.

In closing, the writer would express his high appreciation of the ingenuity exhibited in devising the experiments and the care in their execution, of which the results give ample intrinsic evidence. He also fully appreciates the many difficulties connected with such work, and would extend to the author his thanks for this valuable contribution to the all too scant literature of the subject.

Mr. Walter Ferris.—In October, 1899, the writer made some experiments on a form of Pitot meter, the results of which may be interesting in connection with the author's deduction that the head shown by a pair of tubes may be largely affected by suction at the static opening.

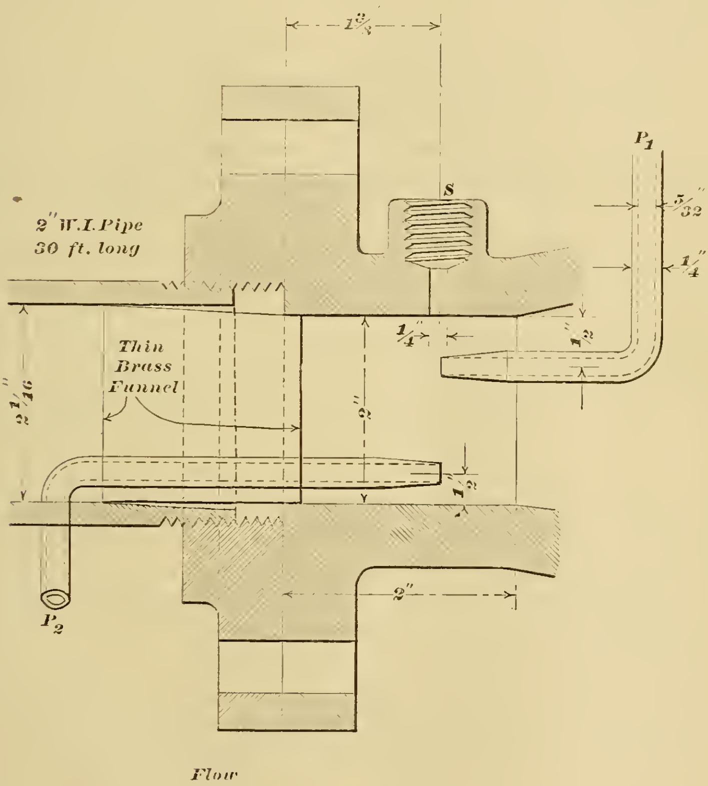
The apparatus, as shown in the accompanying figure, consists of a cast-iron throat piece, bored 2 inches inside diameter and 2 inches long, connected to a length of 30 feet of 2-inch iron pipe. The gap between the flange on the pipe and that on the throat is bridged by a funnel of very thin sheet brass, to prevent agitation of the stream. The water passed through the throat, part of which is here shown, and discharged through about 150 feet of 2-inch pipe into an iron tank 17 feet diameter and 6 feet deep. The depth of water in this tank was measured by a large float, reading on a graduated board, with a home-made vernier. All quantities of water were read, it is believed, within less than 0.5 per cent. of error.

The Pitot tube, as shown in the figure, was separated into two parts,—viz, a static opening, S, which consisted of a $\frac{1}{4}$-inch hole drilled through the top of the throat, and the dynamic opening, or Pitot tube proper, P_1, consisting of a piece of $\frac{1}{4}$-inch (outside diameter) seamless brass tube, $\frac{5}{32}$-inch bore, facing the flow and sharpened off to a knife edge, as shown. With this arrangement of tubes, connectea to a differential mercury gage, were taken the readings of Series A in table below.

At the same time, another set of readings, called Series B, was taken from a second differential mercury gage, one leg of which

was connected to the same Pitot tube, P_1, while the other leg, instead of receiving the static pressure through S, was attached to another Pitot tube, P_2, exactly similar to P_1, except that P_2 was reversed in position, as shown. All these three pressure openings terminated in approximately the same cross-section of the throat.

The duration of each experiment was from eight to twenty-six minutes, read by an ordinary watch, probably within two seconds in each case. The head upon the throat was about 200 feet, the



velocity of flow being controlled by a valve in the discharge pipe from the meter.

From the table of results, it appears:

(1) That the "suction" effect on the reversed Pitot tube, P_2, is very little greater than upon the plain static opening, S. Compare lines 4 and 6, giving the two simultaneous heads, A and B. The ratio of these two heads, as given in line 8 of the table, averages, 1.031, giving only about 3 per cent. increase of head. This does not seem to bear out the theory that a form of static opening

may be employed which will materially increase the head in the tubes as a pair, for in this case the static opening was placed in apparently the best possible position to receive the suction effect, but the consequent decrease in the pressure recorded is very slight.

(2) Comparing lines 4 and 9, as is done in line 10, it is evident that these tubes do give a much greater head (about 60 per cent. greater) than the theoretical velocity head, $h = \frac{v^2}{2g}$, derived from the actual velocity V, as measured by means of the discharge into the tank.

Now, it has been proved, by experiments on the Venturi meter, that the static pressure, indicated by a gage attached to a $\frac{1}{4}$-inch hole drilled through the wall of a closed conduit, is within from 2 to 4 per cent. of the total head less the theoretic velocity head. From this we may infer that the large excess head shown in the writer's experiments is due in some way to the impact of the water against the Pitot tube, P_1, and not to any action on the static openings, S or P_2. Moreover, as the Pitot tube P was situated at a distance from the top of throat equal to one-half of the throat radius, which the Detroit experiments of Messrs. Williams, Fenkell and Hubbell show to be the region of mean velocity, there seems to be no reason to attribute the excessive head to high velocity at the impact opening.

The writer does not feel justified in drawing any general conclusions from a comparison of these experiments with those of the author, partly because the writer has not yet had opportunity to study the author's paper with the care which such an elaborate series of experiments demands, and partly because there is already considerable evidence that the laws governing the action of Pitot tubes in closed conduits and in open bodies of water are not identical. The author's experiments seem to prove definitely that in certain cases the head in the Pitot tube, as distinguished from that in the static tube, is independent of form and is equal to the theoretic velocity head. On the other hand, the experiments herein reported seem to prove with equal certainty that, under the conditions of these experiments, the Pitot head is greatly in excess of the theoretic velocity head, and that this is not due to suction at the mouth of the static tube.

The foregoing facts, together with the experiments of Messrs. Williams, Fenkell and Hubbell, published in the Proceedings of the American Society of Civil Engineers, May, 1901, which showed different coefficients for the same pair of Pitot tubes when calibrated in an open canal and in a closed pipe, suggest the hypothesis that the

head in any Pitot tube will be greater or less, for a given velocity, according to the obstructions offered to the deflection of that part of the stream which strikes the point of the tube and which must change its course in order to pass around it. Near the surface of an open canal, the presence of the tube would cause merely a slight rise or wave in the surface, affecting very slightly the pressure against the tube; whereas, deeper down, the increase of pressure might be expected to be greater. In a closed conduit, the whole mass of flowing water must be more or less accelerated as the tube reduces the cross-section, and the resistance to the transverse motion of the particles of water impinging against the mouth of the tube and passing off at right angles to their former course may be expected to be much greater on account of the confining walls. Hence it seems reasonable to expect that the pressure in the tube, when placed in a closed conduit, should be greater than when in an open stream, as many experiments have shown that it is.

TABLE.*

(1) Experiment No.	138	139	140	141	142	143	144	145
(2) Duration in Minutes.	10.230	Omit. Observations not Reliable.	16.350	16.320	26.560	16.430	8.170	8.170
(3) Actual mean velocity in 2″ throat, by tank, in feet per second.	13.950		5.700	3.240	4.320	6.700	11.720	16.680
(4) Heads, "Series A," in feet of water.	4.790		0.807	0.252	0.478	1.110	3.430	6.860
(5) $V_A = 8.02 \sqrt{A}$	17.560		7.200	4.020	5.540	8.440	14.850	21.00
(6) Heads, series "B" in feet of water.	4.970		0.832	0.277	0.479	1.160	3.490	7.060
(7) $V_B = 8.02 \sqrt{B}$	17.850		7.310	4.210	5.550	8.630	14.990	21.300
(8) Ratio $\frac{\text{Head B}}{\text{Head A}} = \frac{(6)}{(4)}$	1.037		1.031	1.100	1.003	1.045	1.017	1.028
(9) Velocity head $\frac{V^2}{2g}$, due to actual mean velocity, shown by tank measurement.	3.020		0.503	0.163	0.290	0.698	2.130	4.330
(10) $\frac{\text{Head A}}{\text{True Velocity Head } \frac{V^2}{2g}} = \frac{(4)}{(9)}$	1.586		1.593	1.550	1.650	1.590	1.610	1.584

*Computed with slide rule.

Mr. W. M. White.—The writer wishes to express his appreciation of the just criticisms of his paper. A point that the writer wishes to make clear is the fact that the correct formula for the Pitot tube is $V = \sqrt{2gh}$, whether it be considered from the point of view of impact or not. Experiments 1 and 2 show the effect of a "limited jet impinging upon an unlimited surface," as Mr. Williams puts it, but the maximum pressure per unit of area never rises higher than the velocity head contained in the water. Experiment 3 shows the effect of an "unlimited stream impinging upon a limited surface," and shows that the pressure at the point is equal to the velocity head contained in the water.

Mr. Williams, in discussing his tube D, in which the knife edge projects beyond the center of the orifice, says "it will have a higher coefficient than will one in which all sides of the orifice are in a plane." This bears out the writer's statement that the point of a Pitot tube should be a surface of revolution. That tube which converts all the velocity head into static head, exactly according to the law $V = \sqrt{2gh}$, should be the one selected for use, for, if a tube does not do this, it is not a Pitot tube in the true meaning of the term.

There is evidence that the rating of some Pitot tubes, obtained in open canals, does not apply when the tubes are used in closed conduits under pressure. There can be only two causes affecting this result, when the cross-section of the conduit is not materially affected by the introduction of the Pitot tube: First, some change in the law for the conversion of velocity head into static head at the point, due to the increased pressure, or, second, some change in the value of the suction action at the pressure opening, due to the increased pressure.

That the law for the conversion of velocity head into static head can be affected by pressure is hardly conceivable, since the pressure at the point is increased by an equal amount in all directions. That the increased pressure could affect the suction action at the pressure openings seems possible. This suction action is caused by the irregularities of the tube near the pressure openings, as, for instance, the Tulane tube, where the irregularities of the nipple and the tee cause a suction action equal to 39 per cent. of the velocity head. These irregularities distort the flow of the water, causing it to take a direction away from the openings. This flow, striking the surrounding water with constant impact, relieves the pressure at the openings.

When the pressure of the surrounding water is small, the effect of the impact is large, comparatively. As pointed out by Mr.

Fenkell, the distortion could be so great as to admit air into the openings when the tube was used near the surface of the water. When the pressure on the surrounding wall of water is increased, the effect of this distorting force is small, comparatively, and hence changes the coefficient of the tube.

In June, 1900, the writer made some tests* with a Pitot tube inclosed in a 52-inch pipe. The pressure within the pipe was a little less than atmospheric pressure. The tube was worked under an average pressure of 2 feet of water. The side of the pipe was tapped for the static opening, and a pipe led to the Pitot tube gage, connecting it with the point and pressure pipes. The point and static readings were treated as those of a Pitot tube having a constant of unity, and the constant of the point and pressure was calculated to be 0.856. The Pitot tube (Tulane) was afterward calibrated in an open canal under a head of 2 feet, and its constant determined to be 0.849. That is to say, the point of the Pitot tube converted velocity head into static head according to the law $V = 0.993 \sqrt{2gh}$. This is well within the limits accorded to the errors of observation.

An examination of the paper referred to by Mr. Williams will show the same thing when those tubes whose points are surfaces of revolution are considered with the "ring" openings for pressure readings. For four observations, the constant of the point does not vary from unity more than 3 per cent. In fact, a traverse in the 2-inch pipe agrees with the writer's deduction by ½ per cent.

Mr. Ferris's experiments seem to prove exactly the opposite, but the writer does not believe that those experiments are subject to the deductions which Mr. Ferris draws. The areas of the small pipes that are inserted into the 2-inch pipe are so large as to seriously affect its cross-section. The writer takes exception to the position of the small pipe marked P_2 in the figure. In the paper referred to by Mr. Williams it has been shown that slight irregularities in the pipe produce abnormal distortions in the velocity curve. According to that fact, the pipe P_2, owing to its position, may readily shift the point of maximum flow from the center of the 2-inch pipe to the center of the pipe P_1. Whether the maximum velocity would be at P_1 or not, it is readily seen that the velocity there would be considerably increased. Let us suppose, for example, that the maximum velocity does occur at P_1. Under the existing conditions, this supposition seems as tenable as that the average velocity should occur at P_1. According to the paper re-

*Journal of the Association of Engineering Societies, October, 1900.

ferred to by Mr. Ferris, the ratio of the mean to the maximum velocity is 0.81. Assuming that the effective cross-section of the 2-inch pipe is reduced by 5 per cent., owing to the position of pipe P_2, then the mean velocities, as given by Mr. Ferris in line 3 of his table, should be increased 5 per cent. Dividing this increased mean by 0.81, we obtain the maximum velocity, which occurs, according to the writer's deduction, at P_1. In the following table line B gives the velocities thus obtained. The velocities in line B are to be compared with the velocities given in line 5 of Mr. Ferris's table. If the writer's deductions are correct, it is seen that the center of the velocity curve has not been shifted quite as high at P_1. If Mr. Ferris would make a traverse on a diameter with pipe P_1, he could easily determine the correctness or fallacy of the writer's deductions. But a traverse made under the same conditions, in a pipe of

VELOCITIES TO BE COMPARED WITH THOSE IN MR. FERRIS'S TABLE.

No. of Mr. Ferris's Observation	Line	138	140	141	142	143	144	145
Mean Velocity, Line 3, copied from Mr. Ferris's table	A	13.95	5.70	3.24	4.32	6.70	11.72	16.68
Line A x $\frac{1.05}{.81}$	B	18.15	7.41	4.21	5.61	8.70	15.21	21.65
Line 5 from Mr. Ferris's table	C	17.56	7.20	4.02	5.54	8.44	14.85	21.00

the same size, under a pressure of 35 pounds per square inch, described in the paper referred to by Mr. Williams, bears out the writer's deductions within $\frac{1}{2}$ per cent.

The pipe P_2 is not placed in the best position for the greatest suction action. The writer has experimented with nozzles of different shapes moving through water and placed at different angles with reference to the line of motion. He finds that the maximum suction action of a pipe similar to P_2 occurs when the axis of the pipe is at right angles to the direction of motion. The suction action gradually decreases to a minimum as it approaches the position of P_2, with respect to the flow.

The writer regrets that he did not know of the existence of the differential gage, as it would have saved him considerable time and worry in the solution of the problem.

In conclusion, the writer draws the following deductions:

(1) That an impact tube, whose impinging surface is one of revolution, converts velocity head into static head exactly according to the law $V = \sqrt{2gh}$, whatever the pressure of the surrounding fluid.

(2) That only pressure openings which give the true static head of water should be used in connection with the point of a Pitot tube. That is to say that only tubes which have unity as their coefficient should be used.

(3) That Pitot tubes whose constants are unity in open canal ratings will remain unity, whatever the pressure of the liquid. Tubes M and N, Fig. 24, are of this type.

A PLAN TO UTILIZE UNEMPLOYED LABOR.

By James A. Stewart, Member, Engineers' Club of Cincinnati.

[Read before the Club, May 23, 1901.*]

My subject is somewhat out of the usual line of our professional work, but one that I think the engineers should interest themselves in.

It has been well said that the engineer's duty is "to adapt the forces of nature to the use and convenience of man."

There is a great force which, properly organized and managed, will produce wealth sufficient to improve immeasurably the condition of the laborer and mechanic. To my knowledge, this force has never been organized under a simple system, so that it could be made productive and self-sustaining.

In this and in foreign countries, efforts have been and are still being made to better the condition of man through political efforts and the enactment of laws establishing labor bureaus, reducing the hours of labor and making appropriations for public work. This is all well enough so far as it goes, but I believe the true solution of the labor problem is to be reached through the efforts of man in a businesslike way, without the aid of any laws or financial assistance from political governments.

The human force, physical and mental, that is lost in idleness for lack of opportunity or means of being employed is, in my opinion, great enough to produce the wealth of a corporation or trust equal in magnitude to any of the trusts now in existence.

Politicians, labor agitators and economic writers are trying to solve this problem. I believe that it is a problem in engineering, and should be taken up, studied and solved by the profession. No body of men comes in closer contact with the laboring classes than the engineers. No one is in a better position to judge of the value and magnitude of their efforts than is the engineer.

He it is who prepares the plans and specifications for all improvements and starts the army of laborers and mechanics to work. Under his constant supervision they bring the improvement to a successful completion, and then very often, though not always, it becomes his duty to organize and superintend the operating forces.

So that, in the line of his duties, it falls to his lot to be closely identified with an enterprise from the time it originates in the promoter's brain through all the different stages of development, from unimproved land to wealth yielding an income to the capitalist.

*Manuscript received July 31, 1901.—Secretary, Ass'n of Eng. Socs.

There his duties generally end. He is not consulted in regard to the clipping of coupons, as he was never known to have any of his own to clip, and he therefore lacks the necessary experience, through no fault of his, however.

Now, there are reasons why we have no coupons to clip, and each individual can no doubt look back over his experiences and in one way or another account for his lack of wealth. We shall no doubt find many reasons, and each individual's reason may be different from the others; but I believe there is one reason common to us all, and if we can prepare plans and specifications by which this reason can be obviated we shall have solved the problem of the "unemployed."

This underlying reason, common to all, is time lost in idleness, or in not being engaged in profitable employment. If each individual will estimate the number of months lost at the average rate of his salary during seasons of his employment, or, if engaged in private business, the amount of work he might have done had it been offered him at a reasonable profit, I think the total will be a sum great enough to have paid for a comfortable home free of incumbrance.

The home is the foundation of civilization. It represents the wealth of nations and of municipalities, upon which their bonds and credit are based.

Each individual or family must have a home, whether it be one room in a crowded tenement house or a mansion in the suburbs, and the location and character of the home is a fair barometer of the social condition of the occupants.

Now, admitting that the home is a prime necessity to all, and that our weak financial condition is due, in part, to time lost in idleness, the problem to solve is, can we utilize our idle time in the securing of a home? If so, how, when and where?

The engineers and architects are respectfully requested to submit plans and specifications for the solution of this problem.

I am going to present for your consideration to-night a plan which I believe will help solve the problem, and which, if taken up, studied and improved upon by the profession, will lead to gratifying results. Upon the efforts of the laborer and mechanic depend the success of our work, and we should give our best efforts to the amelioration of their condition.

If I can present one single idea that will tend to make work for any one out of employment, my effort will not have been in vain.

Statistics show that 70 per cent. of the people do not own a home, and I propose to build homes for these people by the co-

operation of landowners, material men, merchants and unemployed laborers and mechanics.

I would organize a savings and a building company, the object of which would be to assure the accumulation of an estate to each of its shareholders by giving him employment at or in his own trade, profession or business when he is out of employment, or giving him an opportunity to increase his business in dull seasons. The result of this labor to be deposited with the company and invested by it in the manner best calculated to secure to each depositor fair dividends on the result of his labor.

The affairs of the company are to be managed by a Board of Directors, thoroughly conversant with land values, cost of material and labor, experienced in public works and having the confidence of the people.

I think there would be little trouble in securing all the land necessary, and about 50 per cent. of the material and labor can be secured. Money would have to be secured to make up the remaining cost of material and labor at the start, but after the confidence of the public was once established little actual money would be needed. A simple system of exchange of credits is all that is necessary. When an individual's credit amounts to the value of a house, he could be given a deed to the property and his account balanced. The rentals from ten to twenty houses would pay from 4 to 6 per cent. on the investment, and members not wishing a home would be satisfied with that and would leave their principal to be used in the business.

To give you an idea of the wealth that might be produced in a year, I will give you the difference in cost of buildings erected in Cincinnati in 1898 and 1899, as shown by figures from the Building Inspector's office:

In 1899 the total cost of structures was.......	$2,378,000
In 1898 the total cost of structures was.......	1,736,000
The difference was......................	$642,000

This difference approximately represents one year's loss of material wealth in the building trade alone for the lack of opportunity to invest labor and material in productive enterprises. The same labor that produced $2,378,000 of wealth in 1899 was willing and anxious to have produced the same amount in 1898.

It is an indisputable fact that a majority of the people living in the tenement house are the people whose labor is necessary for the construction of homes, and this labor is idle about three months in a year. This enforced idleness keeps them in poverty when, by

co-operation with land owners, material men and merchants who wish to increase their business, they could utilize their labor during that time in the construction of a home. Three months of enforced idleness, for the labor engaged in home-building, represents a loss to that labor in material wealth of about $1500.

Distributed among the different classes of labor as follows: Common labor, about $90; bricklayers, about $216, and others in similar proportions, one day's labor, invested at 6 per cent., will double in twelve years.

The laborer, at $1.50 per day, for sixty days in the year, would accumulate about $1700. A very comfortable home can be built for that amount of money, and the better paid labor could secure a better home in less time. Banks and building associations are paying larger dividends than this.

It is possible for all men engaged in the building trades to become the owners of their homes in less than ten years, and they will have been paid for in labor performed in time that would otherwise have been spent in enforced idleness.

How many have been able to build a home and have it free from incumbrance in that time by borrowing money from a building or loan association or savings bank? A very small percentage, I think.

The average time required to obtain a home on the instalment plan will exceed fifteen years, and the amount paid in interest and premium in that time will have doubled the cost of the home. And many an unfortunate one has lost his home and all payments made thereon because he could not keep up his interest, premium and dues. The old story, money scarce, dull times, no work for laboring men or mechanics.

Did you ever stop to think how simple and easy it has been made for the people to invest their idle capital in the form of money, and how hard for them to invest their idle capital in the form of labor, the source of all capital?

If you have $1000 or more of idle capital in money, it will not take you more than one hour to get to a savings bank and trust company where you can deposit the money and draw about 4 per cent. interest on it from the day of deposit.

If you have $1 per week idle capital in money you can deposit it weekly in a building and loan association which meets near your home, and will pay you semi-annually about 6 per cent. interest on your money.

In building a home, you start all the wheels of industry to moving. Stone must be quarried from the hill, brick made from

the original clay, trees felled in the forest, iron and lead taken from the mines; that which is not produced at home must be shipped by rail or water to its destination. The engineer surveys the lot and stakes out the house; the architect prepares plans and specifications; the laborers dig the cellar; teamsters haul the material to the site, and skilled mechanics in their respective branches erect the home. With this labor engaged in productive enterprise, it will necessarily increase the labor engaged in distributing enterprise and improve the business of merchants.

Until we have built homes for 70 per cent. of the people who now live in rented property, I see no good reason for men being out of employment or merchants not doing a profitable business. Put men to work in a productive enterprise and establish a system of credits with the home as the basis, which will have the confidence of the public, and I believe the profits in ten years would exceed that of the savings banks, and they are not small. The Union Saving Bank and Trust Co.'s profits are in part represented by the sky-scraper, and that will be a dividend producer for many years to come.

Now, in conclusion, allow me to request you to think of this plan (if you think of it at all) as a business proposition, and a business proposition only. Do not look upon it as a socialistic measure or a political reform of any kind. The only difference between this proposition and a banking institution is that one accepts money deposits while the other accepts money, material and labor deposits, and they would both invest their capital in the same manner.

I trust that this Club will not deem my plan Utopian. All reforms have been regarded as futile until carried to a successful issue. There can be no nobler work for the engineer than to devise some kind of a scheme to capitalize the energies of the self-respecting fellow-laborer out of employment.

OBITUARY.

Benjamin Thomas Lacy.

MEMBER, TECHNICAL SOCIETY OF THE PACIFIC COAST.

BENJAMIN THOMAS LACY, a member of the Technical Society of the Pacific Coast, died at his residence in San Francisco on the 21st of May last. He was long and widely known to the membership, and did much to promote the practical objects of this Association, both as a merchant and as an engineer. His unbounded energy and assiduous labor in conducting the business of the Park & Lacy Company, of which he was the president and chief owner, was no doubt one of the causes that led to his death at the early age of fifty-six years.

Mr. Lacy was born in 1846, at Wexford, on the east coast of Ireland, from which the family removed to Liverpool, England, where Mr. Lacy was educated and apprenticed to an engineering firm in that city, serving seven years and passing through the regular course, including the various departments, as is the custom there. This training laid the foundation of his business life, because, while known here mainly as a merchant, he was nevertheless thoroughly acquainted with the construction and operation of all kinds of machinery, and has always maintained an engineering department in his business.

He came to this country in 1867, and was engaged in the early development of pneumatic drilling machines and compressors at Fitchburg, Mass., and afterward at many places in this country in erecting and operating this class of machinery. He also went to Europe, and at the Mont Cenis Tunnel superintended the installation of the American rock-drilling machines. He then came to Nevada to introduce pneumatic machinery in the construction of the great Sutro Tunnel at Virginia City. When there he met Mr. Lyman C. Park, with whom a partnership was formed to deal in machinery and mining supplies in San Francisco. This firm prospered, and established branches at Salt Lake City, at Portland, Ore., and at Sydney, New South Wales. There have indeed been few if any firms on this coast that have ventured so far afield or taken so comprehensive a view of the trade in any line of business.

About ten years ago he purchased the interest of Mr. Park, and later on founded an incorporated company with a view of some relief from labor and care involved in the management of the extensive business; but the strain had been too great and had sapped his vital powers, producing organic disease that his vigor could not overcome.

Mr. Lacy's environment had always been of an engineering nature. Mrs. Lacy was of the Canning family that for several generations were noted engineers and millwrights in the North of Ireland, she having eight brothers all in this pursuit.

Your committee is glad to present this tribute to one who was a prominent and valued member of our Society, who has done much and his full share to promote the interests of engineering on this coast as well as that of the Technical Society.

Respectfully submitted,

J. RICHARDS,
G. W. DECKER,
GEO. E. DOW,
Committee.

Editors reprinting articles from this journal are requested to credit not only the JOURNAL, but also the Society before which such articles were read.

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EFFICIENCY OF MULTIPLE VOLTAGE CONTROL IN ELECTRIC POWER TRANSMISSION.

BY LEHMAN B. HOIT, MEMBER CIVIL ENGINEERS' CLUB OF CLEVELAND.

[Read before the Club, May 14, 1901.*]

THE use of electricity for the transmission of power has become an attractive problem, especially since the general introduction of electric lighting has rendered the installation of some kind of generating plant a necessity. The progress which has been made within the last few years in the centralization of power-generating units, in the abandonment of long and heavy lines of shafting and in the elimination of complicated belt drives makes it self-evident that this form of power transmission has entered upon a new phase of development. As a result of this modern advance in the use of electricity for power transmission, the methods of applying and controlling have become matters of ever-increasing importance.

That this subject is far more than a technical problem of engineering is evinced by the exhaustive study and experiments made by our ablest mechanical and electrical engineers. While the results of their investigations and experiments have been very gratifying, and have borne fruit in many directions, there is still open a wide field for improvement. Unfortunately, the general trend of investigation has been upon the lines of the character of the current to be used in power transmission rather than in its application.

This controversy, however, has awakened the interest of those closely associated with the development of electrical ma-

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chinery; but the arguments advanced by the advocates of one system or the other, which constitute the bulk of literature available on the subject, concern the improved methods of generating and transmitting this energy, and not its application and control. The arguments in favor of the direct current system over the alternating current system, and *vice versa,* have been of a technical rather than a commercial value, and, as a result, the purchaser has had little opportunity, owing to his limited knowledge of the subject, to exercise his judgment in the matter. When he is inclined to suggest improvements in his own plant in the use of either the alternating or direct current apparatus, along the lines he has found acceptable in those of other locations, he finds that the circumstances are so different that it is difficult for him to determine which system is more applicable to his requirements.

It would be well, therefore, to let the person interested in the use of electric power transmission place in one column the features in which the direct and alternating current machines are alike, and in another those in which they differ, and the results will surprise him. Speaking generally, it is safe to say that direct and alternating current machinery manifests like rather than unlike characteristics, so there is really no justification in the stand taken by one advocate or the other, simply because of a supposed difference in the efficiencies of the two systems.

The prevailing defect in the treatment of the direct or alternating current transmission is the failure to observe that neither system is capable of universal application. Hence, the question of the best system for general use is a problem of great complexity, because we must take into account at once the relative values of the different systems as regards different conditions. The difficulties encountered in one location are not always of the same kind as those met with in another, and it would be folly to pass judgment on the efficiency of one system over the other without considering them from the same standpoint, or under the same conditions. Every intelligent person will admit that conditions may differ in this particular field of engineering to the same extent as in others, and that neither the theory nor the practice can be sound which takes no cognizance of the differences.

It would seem, therefore, that the first requisite for intelligent action in formulating methods of electric power transmission is an accurate and comprehensive knowledge of the existing conditions. It becomes, then, a matter of great importance, first,

to recognize that under all conditions the power generated and transmitted costs something and has a value, and, secondly, that the power imparted to the motor mechanism has a value in proportion to the use made of it. With these data, a foundation will be laid for deciding whether, when the results are not what they ought to be, a remedy should be sought, first, by substituting one form of current for the other, or, secondly, by modifying the conditions so as to make the values of transmission what they ought to be.

It is not my purpose, however, to discuss which form of current should be employed to produce the highest efficiency, nor to recommend any special type of machinery, but, rather, to call your attention to the several ways in which losses occur in the use of the power electrically transmitted. While it may seem necessary, in order to elucidate all the conditions which involve loss of efficiency, to enter into the discussion of the power plant as a whole, the subject embraces topics of so diversified a character, and so extensive in their bearing, that it would be inconsistent with my proposed limit to do more than briefly illustrate the several methods of application and control, and the way in which losses occur.

The word "loss," used in connection with this subject, should not, however, mislead us, nor should we consider it as a principal factor in the operation of this form of power transmission; because, in many cases where the difference in cost between the power produced and the results obtained are not excessive, the difference is principally a price paid for services rendered, and there is no loss.

While the application and control of this energy were the last of the several requisites considered in the early installations, the order of things is at the present time reversed. This reversal is due to the fact that the question of economical use of the power transmitted has become a far more important factor than the cost of production in the early installations. The question of efficiency, in the application and control of the power transmitted, was of less importance than was its use; but as the introduction of this form of energy became more general, and its functions better understood, comparisons were made between the cost of generating power and the amount of work performed by it. It was found that these two factors formed a very wide parallel in many of the installations, due to the fact that the power was wasted simply because the means of saving it were not known.

With the gradual increase in the size of the generating plants, and the increase in the number of motors, the cost of operating was more carefully considered, and this stimulated a closer study of the efficiency of the various methods of application and control. In considering the use of electric power transmission at the present day, there are two ends to the question of economy, with a middle of some magnitude. The practical efficiency of electric power transmission over the old method suggested the centralization of the steam plant, and the rearrangement and location of machinery suggested the use of motors, while these two suggestions, joined together, determined, in a measure, the methods to be employed in order to secure the best results for the money invested.

With these facts before us, we are prepared to determine the efficiency of the several methods used in the application and control of the power transmitted, and to fix a certain value for the work performed. To bring this matter still closer, and to emphasize the importance of considering the several methods employed for the economical use of the current, it seems necessary to define the formula which concerns the question of efficiency. We cannot do this, however, without determining the *value* or *utility* of the current in relation to its employment under different conditions of service. Let us, therefore, decide that the *value* of electricity, as a medium of transmitting power, rests primarily in its application, as compared with some other form of *transmission,* and its *utility* in the degree to which it can be controlled compared with some other *power.* The *value* and *utility* of electric power transmission, when considered from one standpoint, are inseparable, while from another they are no more to be confounded than any other two distinct things.

We will readily understand the value and utility of electricity as a medium of transmission by considering the methods used at the present time for operating and controlling the power in connection with variable speed machines. For convenience we shall divide these under three general heads, namely:

First. Belt transmission with mechanical speed control.

Second. Direct connected transmission with rheostatic control.

Third. Direct connected transmission with multiple voltage control.

Mechanical Speed Control. This method of applying and controlling the power transmitted requires no special mention, for the reason that every one interested in mechanical and electrical

engineering is familiar with the systems now in vogue. The only distinctive feature which this form of transmission possesses over the old system of direct line shafting rests in the reduction of frictional losses incident to the construction. The same counter-shaft losses which, in many plants, amount to nearly double that of the main line are present, and must be taken into consideration as a troublesome factor. No particular economy is obtained in this method of applying and controlling the power transmitted, except in the way of cutting out one or more groups of machinery that are not in constant use, and in shutting down the motor during periods of delay. There are other features, of course, which make this form of transmission desirable, notwithstanding the fact that the excessive losses of countershafting and belting are realized. There can be no question as to the advantage of electricity in many instances, for the reason that it is the only agency of transmission available. But these facts are generally understood, and the value of electricity, as a means of transmitting power, is proportionate to the benefits derived. Therefore, it is *valuable.* Its *utility,* however, under these conditions is questionable, because electricity makes open confession of its inability to do intermittent work or to give variable speeds at constant voltage without loss. Then, again, when the factor of time, in changing the speed of machines mechanically, is taken into account, this form of transmission has no particular advantage over any other system, except perhaps in its being able to make a virtue of a necessity.

In the installation of a system of this character, much depends upon the arrangement of the motor in relation to the machines that are to be operated. The grouping of the machines, of course, will depend upon the length of time each is in commission during a given part of the day. But this method has its limits, and it is a question of a very short time when all forms of belting will be eliminated. To meet the growing demand for motor-driven tools, the machine builders are hard at work trying to design proper speed variation which can be attached mechanically from a constant speed motor. There is nothing at present to recommend in this line, but, undoubtedly something will be gotten up in the near future to suit these conditions.

Rheostatic Control. This system was suggested as a means of controlling the motors applied directly to individual machines, and as a method of eliminating the countershafts and their belt connections. It was, however, a step in the wrong direction, as experience proved.

The supposition that the speed of the motor could be reduced to meet the various conditions of service, by inserting an external ohmic resistance in the armature circuits, is not borne out by the facts. It is found that while the motors would operate at substantially the same speed under variable loads, when the speed of the motor was normal, the ohmic resistance inserted destroyed proper regulation and it could not be automatically controlled. In order to maintain a standard speed less than the normal speed of the motor, it is necessary to move the lever of the speed regulator by hand each and every time the load changes on the motor.

Another peculiarity in speed variation is the fact that the power required on some kinds of machinery when running slowly takes almost as much current as at full speed. Whenever the load driven by the motor varies greatly, the regulation of its speed by means of external resistance in the armature circuit is almost sure to be more or less unsatisfactory, except, of course, where an attendant is always present, as, for example, in operating cranes, elevators, etc.

Many attempts have been made by the manufacturers of speed-controlling rheostats to devise some form of mechanism in which these objectionable features would be overcome. It is difficult, however, to understand how this may be accomplished, because the underlying principles of controlling any current, where its voltage is constant, are exactly the same as the regulation of water pressure where the supply is constant and the demand variable. The relief valve used in hydraulics has its defects, notwithstanding the fact that many years of study and experiment have been consumed in endeavoring to perfect its functions.

But the control of the motor is not the most serious drawback in the use of regulating rheostats, for when the speed of the motor is cut down by resistance in the armature circuit, all current consumed in the resistance box is wasted. It is very much like putting a friction brake on the fly wheel of an engine in order to vary its speed, instead of adjusting the governor. Such practice as this means an enormous waste of current, which must be dissipated in the rheostat, consequently the efficiency of a motor operated under these conditions falls considerably below that of a very poorly constructed line shaft and belt transmission. To bring this matter out more clearly it might be well to give the efficiency of a motor operated with rheostatic control. The motor tested was designed to run at 480 revolutions at normal speed,

and its efficiency at this speed and under full load was about 90 per cent., which is as high as is found in motors of good construction. At one-sixth of its normal speed, or 80 revolutions, the efficiency of the motor was only 12 per cent., showing that 86 per cent. of its output power was lost in the rheostat.

We feel justified, therefore, in saying that the rheostat is unsatisfactory, as regards both its ability to regulate the speed of the motor and its inability to lower the voltage, which it must do in order to obtain variation in speed without excessive loss of current. It would not be inconsistent with the facts, therefore, to state that, by the use of this method of control, electric transmission possesses neither *value* nor *utility*.

Multiple Voltage Control. The gain in the economical use of power, attributable to the adoption of electricity as an agency of transmission, carries with it some uncertainty when its application to motors connected to variable speed machines depends upon some form of mechanical or electrical control. The first method of application and control of the current supply has some advantage over the second, or rheostatic control, but neither has any particular field of usefulness or adaptability. Realizing the importance of the full control of the power transmitted as an indispensable factor in the economical operation of the plant, other methods were sought. All circumstances seemed particularly to invite the application of some system in which the speed of the motor could be controlled by an economical method of changing the voltage.

The Bullock Electric Manufacturing Company was the first to give this subject consideration, and was successful in devising a system in which all the objectionable features of the mechanical or rheostatic control were eliminated. The principal feature of its system is the means of varying the speed of the motor by generating currents of different voltage. This system of multiple voltage, because of its general adaptability to old installations as well as new, marks it as the coming method of controlling the speed of the motor connected to variable speed machines. While this is not new, there are, perhaps, some features connected with it that are not fully understood. It, therefore, seems proper to explain briefly its functions in order to compare the various systems.

This system of multiple voltage control is one which is adapted to varying the speeds of the motor by supplying the armature circuit with different voltages while the fields are constantly excited from any one specific voltage. The advantage

of this system over the two systems just described are, first, it gives the motor a constant torque, regardless of the speed; second, when the motor is set to run at any one speed, it will run at this speed, regardless of the load, and, third, the different speeds are obtained without passing the current through any resistance. Considering this system as applied to existing installations, one of the most important features is that any motor can be run on the multiple voltage system, as it requires no change whatever in the motor. To illustrate one method of supplying the different voltages which, in a measure, is the form of all others, your attention is called to the arrangement of the generators shown in Fig. 1. This consists of two generators, one with single and one with double commutators. Generator No. 1, having two

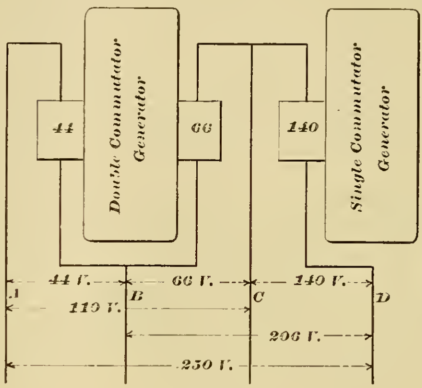


FIG. 1.

commutators, is wound for 44 volts and 66 volts, and generator No. 2, for 140 volts. It will be seen that if we connect the armature terminals of the motor across A and B the armature will receive 44 volts; if across B and C, 66 volts; if across A and C, 110 volts; if across C and D, 140 volts; if across B and D, 206 volts, and if across A and D, 250 volts. This gives the motor six different speeds. As the speed of the motor is almost exactly in proportion to the voltage, the motor will vary in speed from 44 revolutions to 250 revolutions, or in this ratio. Constant speed motors would be connected between A and D, giving 250 volts for these motors, and the variable speed motors would take any current desired to give the different speeds. The voltage is selected for the various speeds by means of a controller, and this may be so arranged that the motor can be reversed and be made to run at six speeds in either direction without any resistance whatever from the circuit.

By the use of this system, the motor would run at a fixed speed, regardless of the load, after the controller was once set for the voltage required to give the desired speed. The torque of the motor would remain constant, regardless of the speed, whereas the horse power would vary as the speed. The diagram shown represents what is termed a four-wire system. This will give six variations of speed. A five-wire system will give ten variations, and a three-wire system, three variations of speed, if the voltages are unequal. Fig. 2, which shows a double commutator machine giving 44 and 66 volts, would give three voltages for the motor, either 44, 66 or 110 volts. In the majority of cases the four-wire system will answer all requirements. In some cases the three-wire system will suit the conditions of service. The system we have just described covers a complete installation

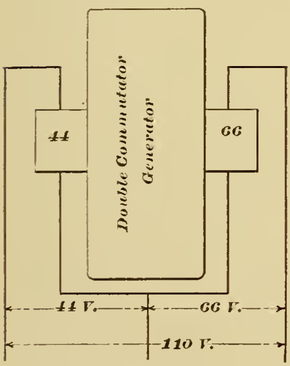


FIG. 2.

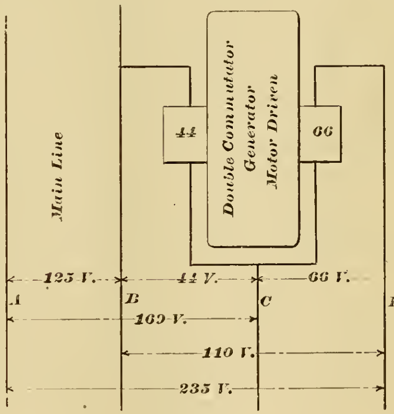


FIG. 3.

and includes the generators. Where a plant is equipped with a permanent generating unit, it is a simple matter to arrange this system in connection with it. Fig. 3 illustrates how this may be accomplished. Assuming that the generator is delivering the current at 125 volts, we would then install a double commutator belt-driven generator and arrange the wiring as shown. Across the terminals B and C we secure 44 volts; across C and D, 66 volts; across B and D, 110 volts; across A and B, 125 volts; across A and C, 169 volts, and across A and D, 235 volts, and the speeds would be proportional. The same plan can be followed whenever the present source of supply is insufficient and some additional energy is required. If the mains are for 250 volts instead of 125, the transformer would be wound for double

the voltages, and if for 500 volts, for four times the voltages, giving the same proportional speeds as for 125 volts. The efficiency of this system, as compared with the rheostatic control, is best illustrated by giving the value of the curve taken from a 25-horse-power motor controlled first by ordinary rheostatic control, and then by the system just described. The efficiency of the motor under rheostatic control was only 12 per cent., whereas with the multiple voltage system of control the efficiency was 70 per cent. There were 19,000 watts lost in the rheostat at this point, whereas there were only 1150 watts lost with the multiple voltage control, the rheostatic loss being nearly seventeen times as great. The reduction of the speed of the motor in both instances was one-sixth of its normal speed.

The particular advantages of this system are that there is no loss whatever in the current supplied, and that the machine is under the absolute control of its operator, and the speeds may be changed as rapidly as required. By the use of this system every loss due to friction of countershaft and belting, resistance in rheostat and delays incident to change in the speed of the machine are eliminated. It would seem, therefore, that this system possesses *value* and *utility* in its application and control.

In conclusion, I would say that the methods of application and control described seem to suggest the use of the direct current rather than the alternating current for operating variable speed machinery. I would say, however, in deference to the prevailing idea of the relation of the direct current to the alternating current, that as neither is a power transmitter pure and simple, as a belt or cable may be said to be, and as both are capable of performing many other functions, the power-transmitting capabilities of each have special fields of usefulness.

DISCUSSION.

Mr. C. H. Benjamin.—I am obliged to approach this subject from the side of the mechanical engineer, and to look for results rather than for methods. Although it is generally understood that mechanical transmission is wasteful, not half of the power developed at the engine usually reaching the machine, this fact does not constitute much of an argument for electric transmission.

In the first place, the cost of power in a machine shop is usually only two or three per cent. of the total expense account; in the second place, electric transmission, either direct current or alternating, either individual or group system, does not show

a marked gain in economy. The average loss, in individual motors belted to large machines, is about 25 per cent., while motors driving groups of machines through line shafts show a loss of from 40 to 50 per cent., if we include friction of shafting and line losses.

I am glad that the author has emphasized the application rather than the generation, and especially the speed control.

When a shop contains a large number of small machines of approximately the same character and of constant speed, it is cheaper to group them and drive them by short-line shafts, with one motor to each shaft, no motor being of less than five horse power. For this class of work the induction constant speed motor is much in favor. It is durable, needs little attention, is not injured by dust or oil and never sparks or burns out.

For larger machines, consuming five horse power and upward, it is more convenient and more economical to use individual, variable speed motors, either belted or direct connected. This means, of course, direct current. The great advantage of electric control over mechanical is in its greater promptness. It takes time to shift gears and belts, which frequently means that it is not done, and loss of efficiency results. The wastefulness of rheostat control is well understood. If the method described by the author will secure prompt control of speed and constant torque, without too much expense, it will be of great advantage in all classes of heavy machinery.

Everything that saves the time of man and machine is of importance.

I had understood that similar results had been attained by varying the strength of the field, *i.e.*, by what has been called commutating the field.

MR. JOHN W. LANGLEY.—The writer of this paper has done good service in directing attention to the importance of considering the economy of the application of electric power, as well as the economy of its transmission, a phase of the subject which, as he says, is very often overlooked.

It is doubtless true that an undue amount of attention has been given to the question of loss rather than to the more important subject of the availability and control of the power electrically delivered. Loss, however, is inherent and inevitable in any system of regulation. In the method of rheostatic control the feeding voltage at the brushes of the motor is reduced, for a diminished speed, by wasting the excess by a resistance, while in the method of variable voltage, recommended by the author, a cer-

tain loss of plant efficiency at the generating end is implied, for when the voltage is dropped the generators do less work and the full value of the plant installation is not being used.

Theoretically, the ability to feed the motor with just the voltage adapted to its speed for the time being is better than to obtain this same voltage by wasting a fraction of a supply taken from a source at a fixed potential; but, since the variable voltage plan requires specially wound generators having multiple windings, the practical economy of this plan takes the purely commercial aspect of balancing the saving in rheostatic losses against the expense of installing special dynamos, good only for this particular purpose, and running them on the average below their normal plant capacity, and, therefore, at less than their normal efficiency.

THE POSITION OF THE ENGINEER IN MUNICIPAL SERVICE.

Address by Alex. Dow, President Detroit Engineering Society.

[Delivered at the annual meeting, April 12, 1901 *]

The Detroit Engineering Society has always avoided any semblance of political action. We have at times discussed matters of engineering interest so closely akin to what we recognize as politics that our discussion took a distinctly political tinge, but the tendency of each discussion was toward the education of our members as individuals and away from any action or even expression of opinion by us as a Society. In choosing the subject of this presidential address I have not forgotten our laudable custom. The intent of this discourse is educational. It is based on personal experience and observation as an engineer, and is offered to you as engineers in the belief that it will be of interest and perhaps of service.

You will find my text in the Detroit *Evening News* of April 5, where one of the Public Lighting Commissioners is quoted as saying, "I used to think that municipal ownership was a good thing, but my experience has taught me that it is impossible to divorce public business from politics. It is all politics, and just now the Public Lighting Commission is composed of two Republicans and four Democrats."

It is quite true that the Public Lighting Commission is suffering from politics,—Democratic politics, labor politics, reform politics, and just enough Republican politics to season the mess. I suppose the labor men and the reformers object to being called politicians. Perhaps they are not such. Perhaps they are merely playing at being politicians,—you know the tale about the man who thought he played poker, but really didn't,—but they are partisans; and it is not the politician, in the honorable sense of the word, but the "offensive partisan," to use the expression invented by Grover Cleveland, who is a discredit to politics. The man who in public service endeavors to represent or to serve a faction instead of to represent or to serve the whole body politic is an offensive partisan. What his faction is or calls itself is a matter of no consequence He may represent the Good Government League, or the Women's Christian Temperance Union, or the Associated Charities, but when he announces that his service as a commissioner or his employment as a subordinate of a commission is in the interest of, or as the

*Manuscript received October 12, 1901.—Secretary, Ass'n of Eng. Socs.

special representative of, any part of the people, and not all of the people, he is a partisan.

In my experience the most offensive partisans have been those who claimed to represent moral agencies. When they were honest, they were doctrinaires; when they were dishonest, their dishonesty overpassed exceedingly the dishonesty of the politician who admits that he is a politician. My experience is not peculiar. A friend of mine who has paid for his knowledge of city councilors in an Ohio city, where there is an organized reform party, tells me that the only difference between Democrats and reformers is that the reformers don't stay bought.

The common form of speech by which we express the offensive partisan is to call him a practical politician. This expression differentiates him from the man who takes an occasional whirl at politics because he has a momentary feeling that it is his public duty to do so. The practical politician calls that kind of a man a mugwump, and I think he deserves the name. I shall use the euphemistic expression in the remainder of this address, and you will understand that when I speak of the practical politician I am calling the person by the name which he has himself chosen.

The interest of the practical politician in any public department is primarily the money paid by that department as wages. The politician believes that the jobs belong entirely to him. He is even more interested in these than he is in the contracts which are given for supplies or for construction. On these contracts he and his friends can only expect a percentage of the profits, but he and his friends are ready to place their names on the payroll of the city for all the money in the treasury. Whether they can earn their stipends is immaterial. Of course, the work must be done by somebody, but the politician believes that if he and his friends are employed in sufficient numbers the work will be well enough done to keep the public quiet without any one wasting too much of his time and energy on the performance of the small part which becomes his share.

You must not suppose that the politician in office is an idle man. He is exceedingly busy,—as busy as the devil in a gale of wind. The trouble is that he is not doing the work he is paid to do. He spends his time in promoting the interests of his party. He attends conventions, sometimes forgetting to get leave of absence, and always forgetting to have his name removed from the time-book. He is active at caucuses, and is a worker before elections,—a very hard worker. And when, after election, his worn-out system requires repose he takes the same cheerfully; still

omitting to notify the timekeeper of his absence from duty. The interference with the work he is paid to do is just about the same as if he went on occasional drunks. The only real difference is that his irregularities are exceedingly regular, being predetermined by the laws fixing the dates on which elections shall be held.

Public opinion has long ago officially and practically condemned the man who allows his pleasures to interfere with his duties, but public opinion has not yet reached the stage of practical condemnation of the man who lets his politics interfere with his doing the work for which he is paid by the public. When it is effectively recognized that politics and dissipations are on the same footing if they prevent a man from doing the work which he is hired to do, public service can be performed as cheaply and as efficiently as is private service.

When a practical politician holds an office which gives him the power of appointing other public servants, he attains his maximum power for mischief. He not merely fails himself to earn his salary, but he employs others of his kind with a distinct understanding that they are to justify their employment by work done in the interest of him and his faction. That they are supposed to make some kind of a bluff at filling the nominal duties of their office is true, but the politician so appointed looks to his sponsor for protection in his idleness and does not in the least hold himself amenable to the taxpayers whose money he eats. He is not the servant of the city, but he is the *"man"* of such and such a boss. Sometimes the "boss" is a recognized party leader, and the appointment is made in the interest of the party. "The party owed me the job after all these years of work for it; I intend to take things easy and have a rest." That is how a man in this city, receiving such an appointment, stated the case, and he is even now resting at the public expense.

To return to my text. My experience is different from that of the commissioner quoted. It has taught me that it is entirely possible to keep public business separate from politics, even the public business of that very commission. My experience has led me to believe it possible to divorce public business from politics after the two have formed such an unholy alliance. To keep them separate in the beginning was the work of an engineer, and I now propose to tell how it was done. Hereafter I may justify my belief that the old condition can be restored.

The first Lighting Commission was absolutely non-partisan. In its constitution there was the usual recognition of each of the great parties, but each of those six men stood for the whole city and never for a moment for his own political friends. That was

as it should be. A bi-partisan board is not a non-partisan board. You cannot neutralize three aggressive Republicans by appointing three equally aggressive Democrats. Two blacks don't make one white, and the result in practice is at best a deadlock. If by any chance a Republican partisan votes with the Democrats, he is called a traitor, and there is a howl for his political scalp.

This non-partisan commission decided that its duties were essentially legislative. Its members were business men who certainly could not give attention to details of commission work. You remember that these commissioners are unpaid,—well, perhaps I should not put it so, but the payment they get is of the kind best described by a tale concerning our fellow-member, Mr. Frank E. Kirby, who served a term as a Water Commissioner of this city. The Water Board of a large Eastern city visited Detroit in the course of a tour in search of information. Mr. Kirby dropped his other duties to entertain the visitors, one of whom in conversation spoke as follows: "In our city there are three water commissioners; we each get $3600 a year. How many are there of you in Detroit, and what do you get?" The answer was grim, but precise, "There are five of us, and we get hell." The first Lighting Commissioners were well paid in the coin named by Mr. Kirby. Some of them are, I think, still receiving small instalments of their salary. Be that as it may, they decided that their duties were legislative, and therein they made a wise decision. They sought as their executive an experienced electrical engineer of good administrative ability. They failed to be satisfied by any of the numerous applicants who asked for the position; they made guarded inquiries concerning a number of men who were engaged in such work as they had to do, and they ended by offering the appointment to a man who was about as thoroughly surprised as any one could be by such an offer. That was me.

From the beginning, the separation of legislative and executive functions was complete. The commission decided on a policy. I reported on and advised as to possible plans whereby that policy could be carried out. The commission authorized the execution of a general plan presented by me, and then it became my duty to carry out that plan, myself selecting the immediate agents and settling the details. On me lay the responsibility for results. Logically to me was given the choice of means.

Given full charge of the work and the force; given power to employ and discharge help; ordered positively to see that each employe earned his pay; to require no qualifications other than citizenship and competence; to disregard all indorsements which

were not supported by my own observation of the work actually done for the commission, it would appear that I should have been able to keep practical politicians out of the service of the Public Lighting Commission. Did I do so? Well, I think I did. I was convinced of it by the fact that the Republican politicians of the city condemned me for a Democrat, and the Democratic politicians cursed me for a Republican. That was at first; after a year or two they sized me up better. Toward the end of my service I had the expert opinion of a recognized authority on such subjects as to whether I had succeeded in organizing a non-partisan force. The authority was the Hon. Hazen S. Pingree. I think no one here will question his competence. The opinion was given to me personally, in explicit language, and at some length. I do not know that it is advisable to quote it in full or verbatim; indeed, my memory fails me. But the salient point thereof was, "You people down there at the lighting plant are political eunuchs." Now, really, I don't like being called a eunuch, and I think that the Hon. Hazen S. Pingree's metaphor is somewhat startling, but it is so thoroughly expressive that I venture to pass it on to posterity by embalming it in this presidential address.

How did I carry out my plan? Well, I began, so far as the laborers and mechanics were concerned, at the top of the long list, which was arranged according to priority of application. I called for these men in bunches, sized them up personally after the fashion of all engineers who have to hire men; you know how it goes; you don't have to be told that some men are not worth a continental; you can see that by looking at them. I questioned them as to their citizenship and previous experience, rated them according to their claims and set them to work. I personally hired each man, and the hiring was a big part of my work. In a short time I could tell whether or not a man was competent. If he showed himself such, he remained in the service. Some of the men employed in this way seven or eight years ago are still on the Public Lighting Commission's payroll. If a man showed himself incompetent, he was summarily discharged. The orders of the commission were that no man should have a time appointment; that each man should be hired from day to day or from month to month.

There was an application blank which had spaces for name and address, trade or profession, previous experience and references. The references were often autographic. The rule that a man should be a citizen and a *bona fide* resident of Detroit led to many of the applicants establishing their status by presenting the signature of one of the aldermen of their ward or some other well-known

Detroit man. Our foreign-born residents almost always secured the alderman's signature before presenting their application. The rule as to local residence was not absolute, but (after my own name) there never was but one selection made outside of the city; that selection was Mr. Walter D. Steele, a former member of this Society, and who became my chief assistant and afterward my successor. Mr. Steele brought to my aid a knowledge of high-tension electric constructions, and particularly of underground cables, such as was not possessed by any Detroit man, and which was essential to the performance of the duties which fell to him.

In the original selection of employes many presented the indorsement of local politicians. During the first three years, which were years of very hard times, there was an unusually large selection of employes available. Capable tradesmen were glad to get work as helpers or laborers, and for every position, excepting those requiring special technical training, there were from twenty to fifty applicants. It would have been possible to fill each such place after turning down every man indorsed by a politician. That would, however, have been a mistake. A selection from men indorsed only by the "goo-goo" element of our citizenship would, I think, have furnished about as large a proportion of utterly useless and worthless employes as could possibly have resulted had none but pernicious politicians been chosen. Some of the poorest specimens of mankind that were tried in the service brought the most magnificent indorsements from preachers and from pillars of churches. I honestly believe the average preacher does not know the making of a decent workman. I must expressly exempt the Catholic priesthood from this reproach. I noticed that a man who referred us to his parish priest was almost always a good find. On the other hand, some of the best men whom I found, including men who are still employed by the commission, carried the indorsements of politicians whose reputations are far from saintly. I don't say that a tough alderman invariably recommended a good man for a job; what I mean to say is that, especially in these years of business depression, the tough alderman could and did furnish from among their constituents enough mechanics and tradesmen, of a thoroughly reliable character, to fill any number of positions such as I had to offer. Of course the tough aldermen sometimes sent worthless men to me, but I had an effective method of dealing with such cases. If the man proved worthless, I summarily discharged him, and then I did not wait for his political sponsor to come to me complaining that his man had been "thrown down." I made the announcement myself to the sponsor, and followed it up by a few well-chosen

remarks in the vernacular which let him understand that it was his business to know that a man was a good, capable worker before he sent him down to the Public Lighting Commission, and that if the said sponsor did not know any better than to send such a damnable specimen as the one just discharged I would decline hereafter to consider any of his recommendations.

I commend this prescription to any of you who may find yourselves in such a position as I then was in. The first dose, if liberal, effects a complete cure.

The places which required technical training were more difficult to fill. I have already mentioned that one place had to be filled by employment of a man from outside the city. The first draftsmen and inspectors were found by inquiry among the manufacturing and technical concerns in town. They were college men, and their coming to the service was followed by a succession of applications for employment from other college graduates, largely University of Michigan men. The names of most of those men have been on the roll of our Society.

The engineering staff of the construction period was formed of these young men, and when the operating force was organized a number of positions were filled from the construction staff. The pay of these places was not high,—$75 per month being the standard. I could not expect to retain such men permanently at the salaries which were possible, but I could and did arrange for a continuous succession in office. There was no place which was not well filled, and behind each occupant of a place there was a possible successor; the final vacancy of the series being a draftsman's position, which could naturally be filled by any graduate of the engineering department of the University of Michigan. The plan worked during my term; the men have assured me that they found their Public Lighting experience of value, and I am proud to say that they are all to-day filling positions of responsibility with credit to themselves and to their earliest employment.

I see in the press that one of these positions, formerly filled by a graduate engineer, is vacant, and that a competent man cannot be had for the pay. Well, I think the trouble is that a competent man will not take the place under the present limitations. The pay is plenty, and if the place at the salary named were vacant in one of my plants instead of in the city plant it would be filled mighty promptly by an Ann Arbor man.

The steam engineers and similar expert mechanics were selected from the list of applicants. In these classes the plan of putting a man to work and seeing what would happen could not be

tried with the same freedom as was permissible with laborers. An incompetent engineer might wreck an engine in demonstrating his incompetence; or an unskillful electrician send himself to paradise by the electric route, and thereby cost the city $5000 or so. It is really remarkable how valuable such a man becomes after he is dead. But the method was modified only in degree, not in kind. A man was first questioned and then tried. His indorsements counted for nothing, his politics for less than nothing.

The relations of the plant to what is called "union labor" were very early defined. The first commission announced that it recognized citizenship and competence as being the only essentials for employment. It classed union labor affiliations together with politics and religion, as being immaterial so long as they did not interfere with the performance of a man's duties. It resulted that we made no inquiry as to a man's being union or non-union, and that naturally a large proportion of the men employed were union men. I think the ground taken in the matter was solid, and that it is the only ground which promises permanent freedom from trouble.

It was not sufficient to obtain employes who were free from political obligations. It was necessary that they should remain clear of such entanglements. Our rule in the beginning was clearly stated, and it was reiterated from time to time as occasion required. It was that every employe should have opportunity to vote at primary and regular elections; that there should be no inquiry as to how or for whom he voted, but that no employe should on any pretense engage in what is called party work. A report that an employe was making himself notable in politics caused him at once to be called on the carpet and notified that a persistence in such activity would surely lead to his dismissal. In the early days of the commission it was necessary, in more than one case, to warn men individually of the consequence which would follow their persistence in political activity. These warnings took the form of a statement that the Public Lighting Commission was non-partisan; that the retention on the roll of an active partisan of either party would lead to demands from the other party that some equally active partisan of that stripe should be employed; that the commission did not propose to engage in any such balancing of evils, and that therefore the employe must limit his activities or quit the service. No man was ever discharged for political activity. One man resigned with the friendly statement to me that he thought he could better himself otherwise by his political work, and that he therefore preferred to sacrifice his present job. Anonymous charges were occasionally made that men were discharged because

of their politics, but the record was easily cleared. These charges were all made in the early days, when each party said I was a vile tool of the other party.

For five years—three years of my service and two years of my successor's term—the relations of the commission to its electrical engineer were unchanged. You will recognize that these relations were essentially those of a board of directors of a corporation to their general manager. In my own case they were exactly the relations which I now hold to the directors of the corporations whose property I manage. They were the relations which exist in every such department in every city whose work is well done and free from political taint. Instances can be multiplied not only of the successful operation of this distribution of duties, but also of the evil results following when any other distribution is essayed. The Chicago newspapers have just furnished an excellent illustration of success and of failure. The success is in the management of the South Parks. In the past and in the present the South Park Commissioners have performed precisely the duties of a directorate of an incorporated company. The name and title on their letter heads, "J. Frank Foster, general superintendent and engineer," means just what it says. Mr. Foster is general superintendent in fact as well as in name. The West Parks have been managed on the other plan. The commissioners have been partisans, and have appointed partisan employes. The general superintendent has too often been chosen for his efficiency as a party worker. The engineer has always been a subordinate, and too often a negligible quantity in the equation. I speak from knowledge, because I have done engineering work on behalf of each of these municipal bodies. The results of the two systems are summed up by the published cost of maintenance per acre of each system. The average cost of maintaining the West Side Parks is $498 per acre per annum. The average cost of the Washington Park is $220 per acre per annum. And those who know their Chicago and can mentally compare the two park systems will promptly agree with the newspapers that the conditions of the two systems are in the inverse ratio of the moneys spent upon them.

In Canadian cities the man in charge of public works is usually a civil engineer, and he is actually in charge. The Public Works Committee has legislative functions only, and a law duly enacted, not merely a ruling of a commission, prohibits the activity of any city employe in politics.

I have spoken of the successful operation of the public lighting plant while the functions of the commission and the engineer

remained clearly defined. It is now in order to tell what happened when this definition became hazy. After five years' operation of the plant, ill-advised economies, insisted upon by the board in direct opposition to the advice of the engineer, caused a strike of the arc lamp trimmers. The question of detail was whether the trimmers did or did not do enough work for their pay; whether, in fact, their duties were proportionate to their wages; whether they had what in the newspaper discussion at the time was called a "snap." I think the trimmers' duties were no snap, and I know whereof I speak. A man who trims sixty open lamps on a circuit of average length daily, Sundays included, summer and winter, in fair weather and in foul, in the early hours of the summer morning and in the bitter sleet storms of our winter and early spring, has no snap if he does his work properly. Electrical Engineer Steele told the commissioners this. They overruled him. Be this minor fact as it may, the major fact was that the commission, to secure a small economy of operation, overruled its executive officer and ruined the discipline of the plant. The damage to the commission, directly and indirectly, by loss of discipline from that day to this, by the loss of capable employes and the expense of educating others, has offset many times the saving which was expected to be made. The trimmers struck, as I have said, and thereby put themselves in the wrong. They had no right to conspire to put the metropolitan city of Michigan in darkness. They forgot they were public servants when they planned such a stroke. That also is a minor detail. The major fact was that the commission assumed control of details which, even had it been competent to judge, it could not personally oversee, and deliberately permitted employes to feel that they had a grievance.

The engineer did his best. He won the strike for the commission, feeling that his duty to the city overrode his sympathy for the men; but thereafter he avoided responsibility, knowing that he could not depend on the support of his directors, and the clamor raised by the aggrieved employes had its unavoidable result. The appointing power, the mayor of the city, tried to remedy the harm done by nominating a commissioner who undertook to specially represent these employes, and who entered on his duties with a prejudice against his associates. This appointment was followed by another; this second nominee frankly declaring himself the special representative of organized labor. Partisans both of them, these commissioners; well meaning, no doubt, but limited in their action by the circumstances of their appointment, carrying to their duties not a receptive mind, but a preconceived hostility to the past

management. At meetings of the board charges and counter-charges, criticisms and squabbles took the place of frank discussion and of willing submission to the decision of the majority. Tale-bearing by employes was encouraged, different members assuming the protection of different employes or cliques of employes. Matters of detail took up the time of the board, and business was impossible. The plant kept on going from sheer inertia, but the engineer very early concluded that he should end his connection with the institution. He had been wiser for himself, I think, had he come to this conclusion a year sooner than he did; but he, like almost all engineers, was faithful to his salt and tried to do the best for his masters, the public, under adverse circumstances. He economized to a fault; he left his machinery in perfect condition and a surplus of over $50,000 in the treasury. The older commissioners finally gave an opportunity for the restoration of harmony by resigning almost in a body, and new nominees of the mayor, on whom, by these resignations, has devolved the appointment of every present member of the commission, accepted appointment to the vacancies.

Had the commission then reverted to the original system of operation, all might have gone well. Seeing that all personal difficulties had been eliminated, they could have resumed their proper legislative duties, placing the executive responsibility in the hands of one competent engineer. If a local man were not available, they could have sought for such an engineer beyond the city, as did the first commission. Unfortunately, the factional spirit still survived. Employes and ex-employes who had given aid and comfort to the commissioners now dominating during the time when they were a minority apparently had to be taken care of, and these commissioners found themselves the representatives of a faction of the most impracticable kind. A general superintendent was chosen, but he is superintendent in name only. When appointed he did not know the elementary principles of electrical generation and distribution, and he thereby became dependent on one of the re-appointed ex-employes, who was nominated as his assistant. In the public reports and specifications of the commission there is nothing to indicate that during the past year the general superintendent has learned any more about the electrical business than he knew when he started. I regret to say also that these reports and specifications indicate that not merely the general superintendent lacks essential knowledge, but that the assistant is far from having sufficient engineering ability to make good the deficiencies of his chief. It seems ridiculous that a plant which has sent a dozen smart electrical engineers to profitable employment elsewhere should

not be able to find one able man to take intelligent charge of its own affairs. A private plant, offering the same salary, would have found such a man very promptly.

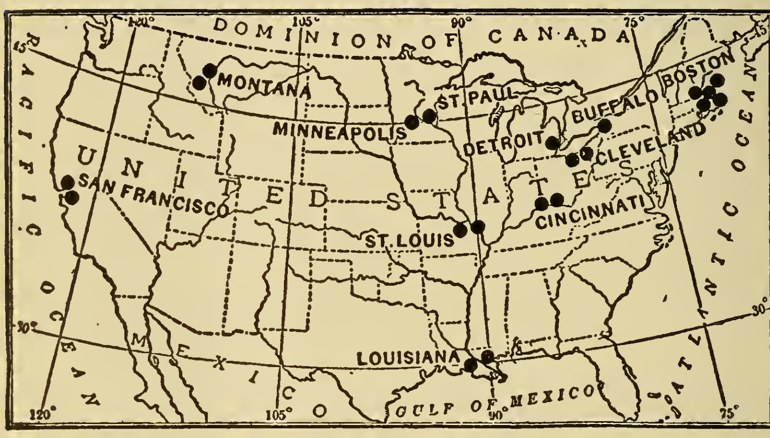
Of course (as shown by my text) the belief has gone abroad that partisan politics have dominated the selection of employes by the new commission. There is too much evidence in favor of this belief to allow one to contradict it lightly. There is a good working majority vote in the commission, and under those conditions it behooves the majority to be careful of its appointments if it desires that its motives shall not be impugned. To appoint as a general superintendent a person who has been a practical politician since the memory of man runneth not to the contrary is a proceeding subject to criticism under the best of circumstances. When the person so appointed knows absolutely nothing about the business he is running, when he and his assistant jointly send around to their subordinates a subscription paper inviting the donation of campaign funds for the party having the majority vote on the Public Lighting Commission; when other appointees to office are also notably party workers, and either without electrical experience or with an experience which is a record of failures, it seems to be a prejudged case that politics control the department.

The financial results do not clear the record. The past president started in with a remarkable program of proposed economies. He announced that expenses could be reduced $20,000 per annum. During the year of his control the expenses apparently have been increased to the tune of $10,000 per annum, and for the first time in its history the commission comes before the Board of Estimators reporting that it will apparently have a deficit at the end of the current fiscal year. That result indicates that there was something wrong with the program, and increases rather than decreases the evidence against the present system.

My conclusion is that a public works department can be operated efficiently and economically on the same lines as is the service of a private corporation; the commissioners assuming the duties of the directorate of such a corporation and the general superintendent, who must be a thoroughly competent engineer, performing all the executive duties. I can admit no exception to this rule. I am aware that in some organizations the peculiar knowledge of individual directors makes their advice exceedingly valuable in the executive department. This was the case in the first Public Lighting Commission of the city of Detroit. Of that commission, there was not one man who had not a general knowledge of the apparatus and methods involved in the electric lighting business;

three of these had served as directors of electric lighting enterprises. The factory of one was a pioneer in the use of electric power distribution, and the commissioner who knew the least of electrical affairs was surprisingly familiar with the routine and costs of a model street railway plant in which he had an interest. Two of the members had technical knowledge and ability which brought them, in the course of their business, a large recompense, and which they gave freely to the service of the city of Detroit. One of these men had been a pioneer in telephone, electric light and electric railway developments, and he is now an officer and director of one of the largest telephone companies in the Middle West. The other, whom I may name, seeing that he is dead, Mr. George Howard Lothrop, was reputed the best authority on electrical patents west of the city of New York. The advice of these men was constantly sought by me as the executive officer of the Public Lighting Commission, and it was always freely given and always valuable. I have indicated sufficiently the peculiar fitness of the first Lighting Commissioners of this city to take charge of detail and to perform the executive duties of their department, and yet it was these commissioners, who knew exactly what they were doing and who were, without exception, better fitted for their public work than any of their successors have ever been, who positively declined to depart from their legislative functions and who insisted upon the assumption by their general superintendent and engineer of the full responsibility and the full authority which his executive duties required. It has remained to men of less knowledge to initiate the contrary policy and to fail in it.

What has been done can be done. Let the Public Lighting Commission of the city of Detroit re-enact the rules of the first commission. Let it place the execution of these rules in the hands of a general superintendent who shall be—who must be—a thoroughly competent electrical and mechanical engineer. Let the commission confine its members to their legislative functions, and loyally support its superintendent in his executive duties. Then there will be again a Public Lighting Department free from politics, free from partisans, economical in operation and a model to be followed not only by other municipalities, but by private corporations. Go outside of Detroit if necessary to find the right superintendent. If he is an honest, capable engineer,—and an engineer, to remain in his profession, must be honest and capable,—his freedom from local acquaintance and entanglements will tend to his success.



DOMINION OF CANADA
PACIFIC OCEAN
ATLANTIC OCEAN
UNITED STATES
MEXICO
GULF OF MEXICO
MONTANA
ST. PAUL
MINNEAPOLIS
BUFFALO
BOSTON
DETROIT
CLEVELAND
SAN FRANCISCO
CINCINNATI
ST. LOUIS
LOUISIANA
120°
105°
90°
75°
45°
30°

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THE ORE-HANDLING PLANT AT THE CARRIE FURNACES, NOS. 3 AND 4, OF THE HOMESTEAD STEEL WORKS OF THE CARNEGIE STEEL COMPANY.

BY W. L. COWLES, MEMBER, CIVIL ENGINEERS' CLUB OF CLEVELAND.

[Read before the Club, September 24, 1901.*]

THE reduction, in recent years, in the cost of producing steel has come about very largely through the elimination of manual labor and the substitution therefor of mechanical appliances. This substitution of machinery for men has taken place all along the line, from the first removal of the ore from its bed by steam shovels to the automatic loading of the finished rails on cars ready for shipment, and at every stage in the transformation of the ore into the rail, when a machine has replaced a man, if the machine has been wisely designed, properly installed, and efficiently operated, cost has been reduced and a cheaper final product made possible.

It is the intention of the author in this paper to describe briefly the method of accomplishing one stage in this transformation, as seen in the handling of ore and limestone from the incoming car to the furnace top at the Carrie Furnaces, Nos. 3 and 4, of the Homestead Plant of the Carnegie Steel Company at Rankin, Pa., through appliances largely designed and installed by the Brown Hoisting Machinery Company.

These furnaces are situated on the north bank of the Monongahela River, and extend from the river to the Pittsburg and Lake Erie and Baltimore and Ohio Railroads, the general arrangement

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of the plant being shown on general plan No. 1, only those tracks, however, having been included which constitute a portion of the ore-handling system.

By referring to the profile on this plan, it will be seen that the tracks used for handling the cars of ore and limestone to and from the car dumper, or tipple, are laid on grades especially designed to suit the plan of operations as described below.

The cars of ore and of limestone, upon being brought into the yard, are first made up into trains, having regard to the relative quantities and kinds of ore and limestone with which it is desired

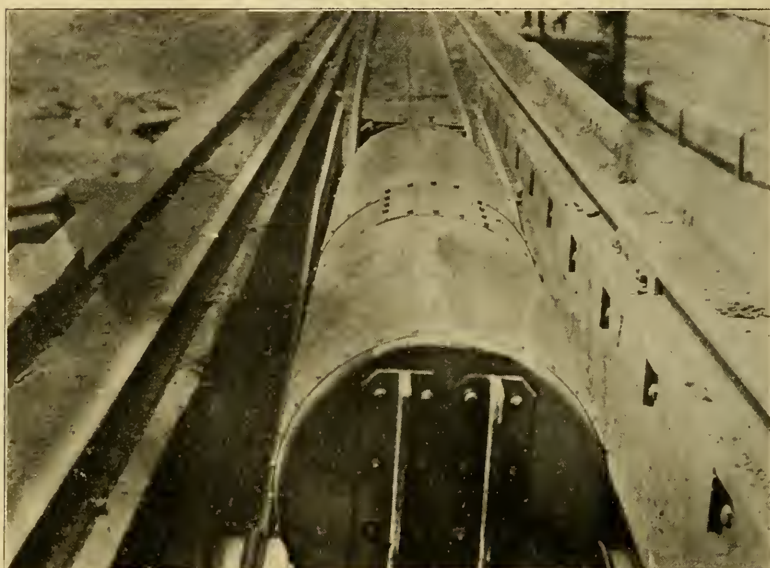


FIG. 1. GROUNDHOG.

to fill the bins, and these trains are then switched onto the tracks marked "Inbound to Dumper," the locomotive pushing the train on one track in toward the dumper until all the cars are beyond the apex of the first grade, when all brakes are set and the locomotive runs back to push up the train on the other track. The brakes on the first car of train No. 1 are now released, and the car starts down the grade by gravity and its momentum carries it beyond the pit wherein is placed the disappearing car, or "Groundhog," as it is sometimes termed and its motion is checked by the ascending grade between this point and the dumper. The groundhog, shown in Fig. 1, consists of a small but strongly built car, of such a width that it can descend into the pit.

which is placed in the center of the track and upon the walls of which are laid the rails of the standard gage track. The groundhog travels on a narrow track laid between the rails of the standard gage track, and is operated by means of a wire rope

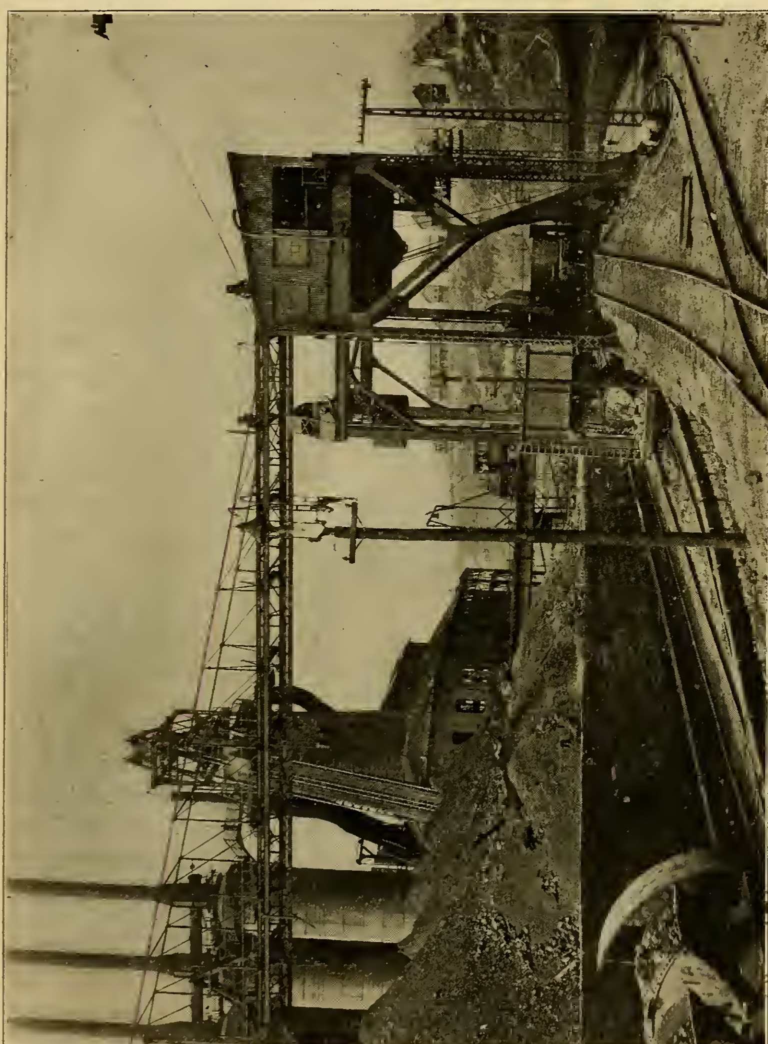


Fig. 2. Tipple.

leading to a drum in the engine house of the dumper, where it is controlled by the one operator who has charge of the entire mechanism of this portion of the plant.

When the loaded car has reached the point at which we left it, the groundhog is made by the operator to rise from the pit,

and, coming up behind the car, it pushes it up the grade and onto the section of level detached track which forms the floor of the dumper. The car dumper, or tipple, shown in Fig. 2, consists essentially of a massive frame, in the shape of an irregular U, hinged at one side, and having attached to the other side wire cables leading to drums in the engine house above, by means of which the frame, or cradle, may be made to revolve about the 10-inch shaft which forms part of the hinge. The engine house is supported by columns, with heavy bracing, designed to carry the constantly changing loads which come upon them during the revolution of the cradle. A counterweight is attached to the cradle by means of wire cables passing over sheaves in the upper part of the fixed framework, and is so adjusted that its weight assists the engine in lifting the cradle at the beginning of its revolution, and, again, in retarding its motion after the center of gravity of itself and loaded car has passed over and beyond the hinge. When the car has been properly located in the cradle, the groundhog runs back by gravity to its pit, ready to repeat the operation with the next car.

It may be stated here that, while this method of placing the cars in the dumper was the one designed for and at first used at this plant, and is the same as is successfully used at other points, it appeared, after it had been in operation for some time, that the groundhog could profitably be dispensed with, for the reason that in this case the yard room was limited, the extent of track which could be devoted to the incoming cars was insufficient and the permissible grade was not great enough to insure rapid handling. The number of cars which could be accommodated on the down grade was not great enough to permit any other use of the locomotive while these cars were being dumped, and it therefore stood idle during this time. It was therefore determined to remove the groundhog and use the locomotive continuously in pushing the string of cars one by one onto the dumper, and this method is in operation at the present time.

Meanwhile the car in the dumper has been secured to the cradle by means of horizontal and vertical clamps operated by hydraulic power, and is being lifted and overturned, as shown in Fig. 3, until the contents, guided by a steel apron extending the entire length of the car, are emptied into a bin having a capacity of about two large carloads. The cradle and empty cars are then returned to their normal position, when, after the clamps are released, the following car, coming onto the dumper, pushes off the empty car. By referring again to the profile on

general plan No. 1, it will be seen that beyond the dumper is a steep descending grade (9.8 per cent.), followed by a level portion, which is occupied by a spring switch set for the return track and beyond this again is a still steeper ascending grade (20 per cent.). These grades are so related that the energy acquired by the car

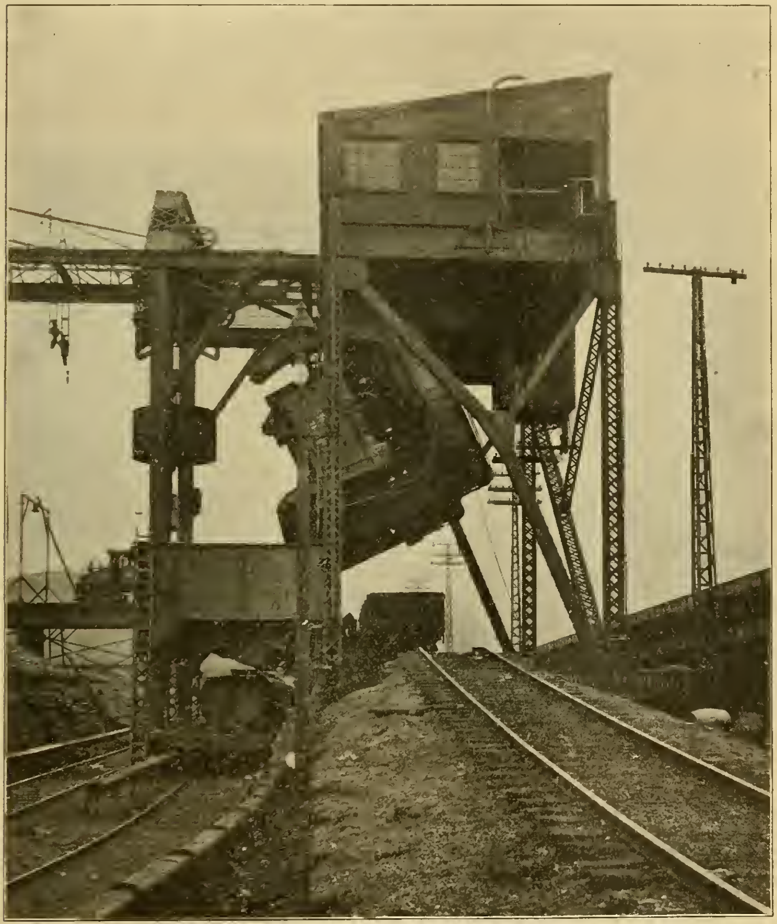


FIG. 3. TIPPLE.

in descending the first grade, making allowance for the loss by friction, carries the car across the level portion, through the spring switch and up the last grade just far enough to fairly pass the point of the switch. When returning, the energy again acquired will carry the car around the curve, by the dumper and down the track to the storage for empties.

A buffer is placed at the end of the track, but is rarely touched by the car, which usually comes within a foot or two of it, when its energy is entirely absorbed and it starts on its return trip. The car dumper is capable of handling thirty 60-ton cars per hour, or 18,000 tons per day of 10 hours. This capacity cannot at present be continuously realized, as the appliances for taking away the ore are not of equal capacity. They are sufficient, however, for the needs of the plant as it now exists, and the excessive capacity of the dumper will provide for a large extension of the plant in the future, if desired. The capacity mentioned has been reached in practice,

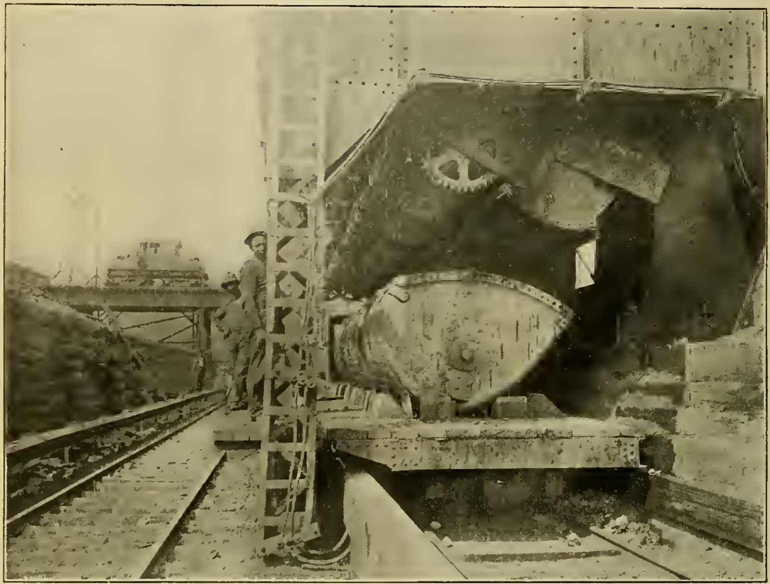


Fig. 4. Gate Mechanism.

sixteen cars having been dumped in thirty-two minutes, when it became necessary to cease operations on account of the bins being full. The largest number of cars dumped in one day is 171.

The dumper bin, as seen in Fig. 3, is divided into eight compartments, each compartment being provided with a chute and gate. These are so spaced that when the car with buckets is properly placed on the track below the bin, each alternate chute will deliver into one of the buckets, which thus are quickly filled without further shifting of the car. The gates are operated by means of a special motor attached to a shaft which extends the full length of the bin, and which has a clutch opposite each gate, enabling the operator, by throwing in any clutch, to open or

shut the corresponding gate. This mechanism may be seen in Fig. 4, which also shows clearly the conduit which carries the wires for supplying current to the cars. These cars, shown in Fig. 5, and with loaded 10-ton buckets in Fig. 6, are made in pairs, coupled, for ease in passing around curves, each car having its own motor, but both controlled from the end of one car, which is fitted with a cab. The track upon which these cars operate, called the transfer track, consists of a straight track extending the whole length of the ore-storage yard, with a connection to the system of yard tracks, and a curved side track passing under the

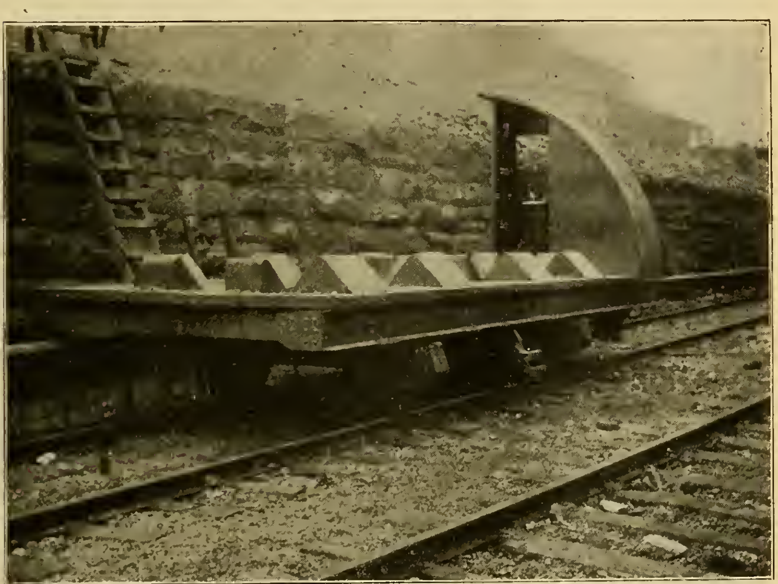


Fig. 5. Bucket Car.

dumper bin, the spring switches connecting the two being so placed that the cars will first run through, and then, returning, follow their proper track, thus making the circuit continually without the necessity of any hand switching. Space is provided on these cars for four buckets, but only three places are occupied when the car leaves the bin, one place being left for the last bucket taken full from the preceding car, which, having been carried away and dumped while the car of empty buckets moves away, is returned to the new car of loaded buckets which has taken its place. This car is stopped opposite the point where it is desired to deposit the contents of the buckets, and under one of the bridge tramways which has been placed at that point.

There are two of these bridge tramways, shown in Fig. 7 and in plan No. 2. Each bridge tramway consists of a central span of 250 feet 3 inches, with a cantilever 160 feet $\frac{1}{4}$ inch long extending over the transfer track, and another cantilever 147 feet $9\frac{1}{4}$ inches long extending to the other end of the stockyard, making a total length of 558 feet $\frac{1}{2}$ inch, end to end of stringers, or a total trolley travel of 540 feet 1 inch. At one end of the central span this superstructure is supported by a steel pier 62 feet high above the yard level, having a base 19 feet 6 inches x 15 feet, and at the other end by a shear leg of the same height, having a spread at the bottom of 20 feet. The general construction

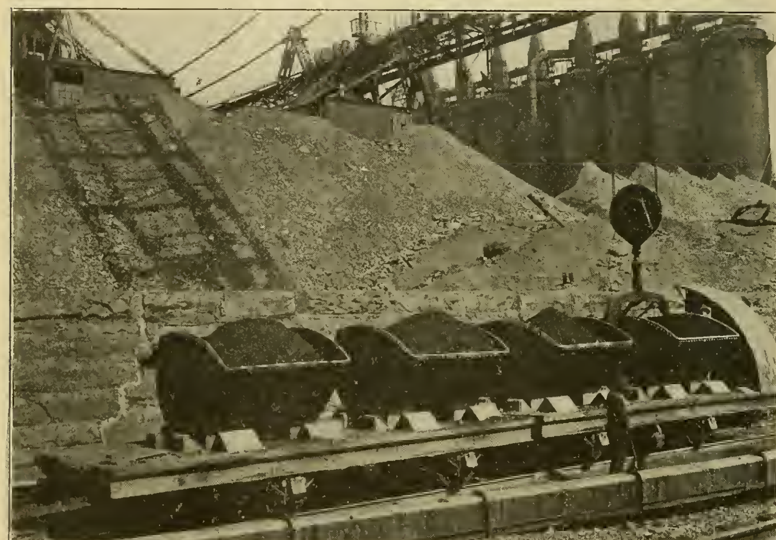


Fig. 6. Bucket Car.

is shown on general plan No. 2, from which it will be seen that the pier rests upon a platform of girders, which in turn is carried by double trucks, while the shear leg is carried directly by two sets of equalized double trucks. The whole construction runs upon tracks laid on top of the parabolic ore and limestone bins which will be referred to later. The motive power is supplied by an electric engine consisting of two 135-horse-power Elwell-Parker motors in an engine house located on an extension of the platform which carries the pier, and supported by another set of double trucks. Power is transmitted to the four sets of trucks under the engine house by a system of shafts and gears, so proportioned as to develop a speed of 75 to 100 feet per minute. By means of similar

shafts and gearing, rising to the top of the pier, passing across the bridge and thence down to the trucks supporting the shear leg, corresponding motion is imparted to the latter. The bridge is not rigidly attached to its supporting pier and shear leg, but at the pier end it is free to revolve, within limits, about a pin passing through the center of the pier cap, the bearing plates of the bottom chord resting on nests of conical steel rollers at the pier top, while at the shear leg end the bridge is carried by a yoke which is suspended, by means of a $4\frac{3}{4}$-inch steel saddle rod, from a socket casting, which in turn rests upon a ball casting on top of the shear leg. This construction permits of a skewing of the bridge to the extent of 1 foot in 9 of length. The tilting of the shear leg, due to this motion, is taken care of by providing ball-and-socket bearings between the feet of the shear legs and the trucks.

The compression chords of the bridge and cantilever are constructed of channels and plates. The tension chords of the cantilevers and their back stays consist of eye bars, while those of the bridge are of wide flat plates. The main posts over the pier and shear leg are of channels laced, but all other posts are of extra strong gas pipe of varying sizes. All tension diagonals are made of round rods of B B iron, and braces of gas pipe.

Between the trusses of the bridge are transverse floor beams supporting two lines of stringers, suspended below them, and upon these stringers runs a trolley from end to end of the bridge, the pier and shear leg being so designed that there is free room for the passage through them of trolley and bucket, all bracing being omitted at those points and the effect of wind pressure and other horizontal forces being taken up by bending stresses. This trolley is quite different from the ordinary type used in these machines, in which the hoisting rope leaves the main sheaves centrally and runs free to the ends of the structure. In this case the length from end to end is so great that the sag in the rope, when the trolley is at one end, would cause it to drag on the ore pile, and it became necessary to devise some means of preventing this condition. To this end, the rope, which, on account of the high stress, is made double, after leading off from the main sheaves, is carried by tilted deflecting sheaves to the sides of the trolley, one part to each side, whence it leads out in each direction over a series of sag carriers suspended from the trusses, and thus placed far enough apart to permit of the free passage between them of the block and suspended load. The trolley will pick up the rope as it passes over a sag carrier, and, as it proceeds, the rope settles again into its place. These sag carriers, consisting of small sheaves supported by the

depending frames, may be seen in Fig. 2, while the trolley is half hidden behind the counterweight framework shown in Fig. 3. Despite the precaution taken to guide the rope into the sag carrier, as it settled down from the trolley, it was found that it

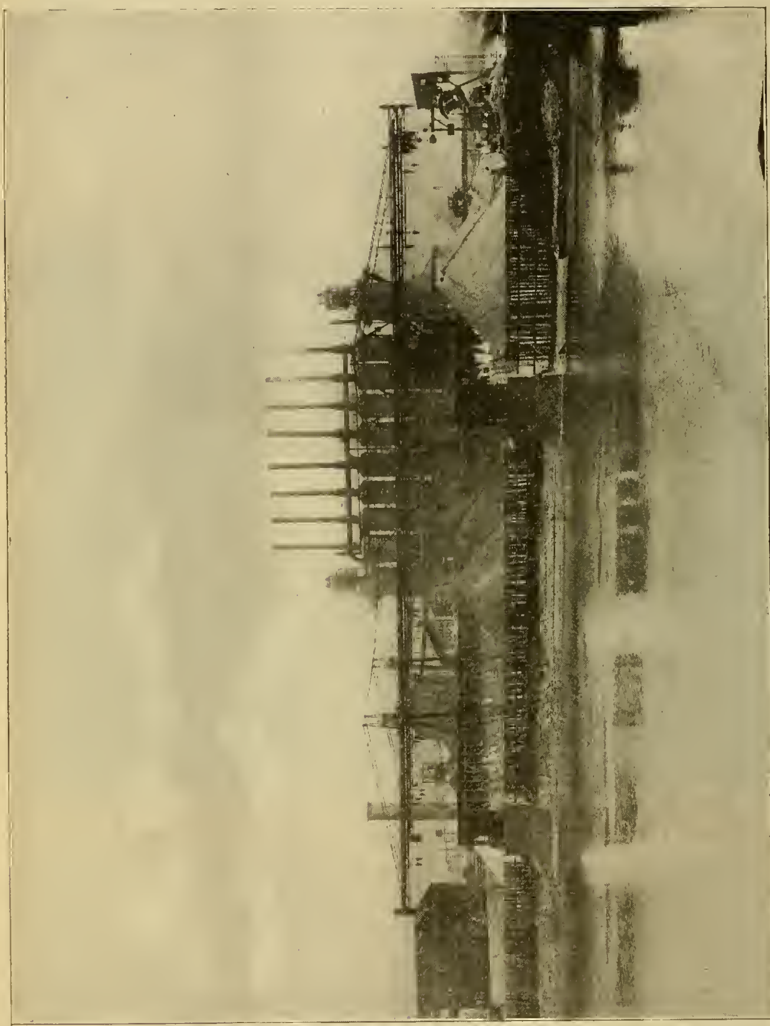


FIG. 7. BRIDGE TRAMWAYS.

would occasionally flop over the side. To prevent this, the inner guard of the sag carrier was increased somewhat in length, and a steel wire rope was stretched from tip to tip throughout the entire length, with the result that, if the rope should so flop out of its guide, its own tension caused it to follow the guard rope back over the tip and into its carrier sheaves.

From the trolley is suspended, by means of a block and clevis, a detachable bail which may be attached quickly to any bucket or detached from the same at will.

The hoisting rope, from which hangs the block, and which in this case is double, of $\frac{7}{8}$-inch plow steel, leads from a drum in the engine house, forming part of the engine already referred to, through a system of deflecting sheaves, to the top of the pier, thence along the bridge, supported at intervals by the sag carriers already described, to one end of the same and back to the trolley; thence, after passing down to the block and up again, to the other end of the bridge, to which it is fastened by a spring buffer. Winding upon two other drums in the engine house are the so-called

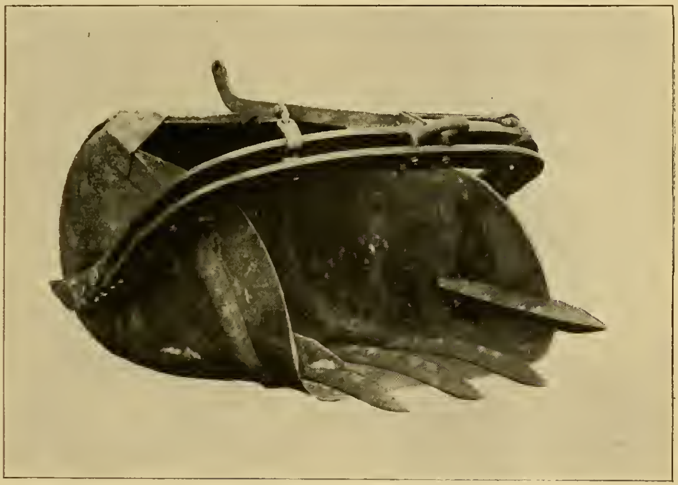
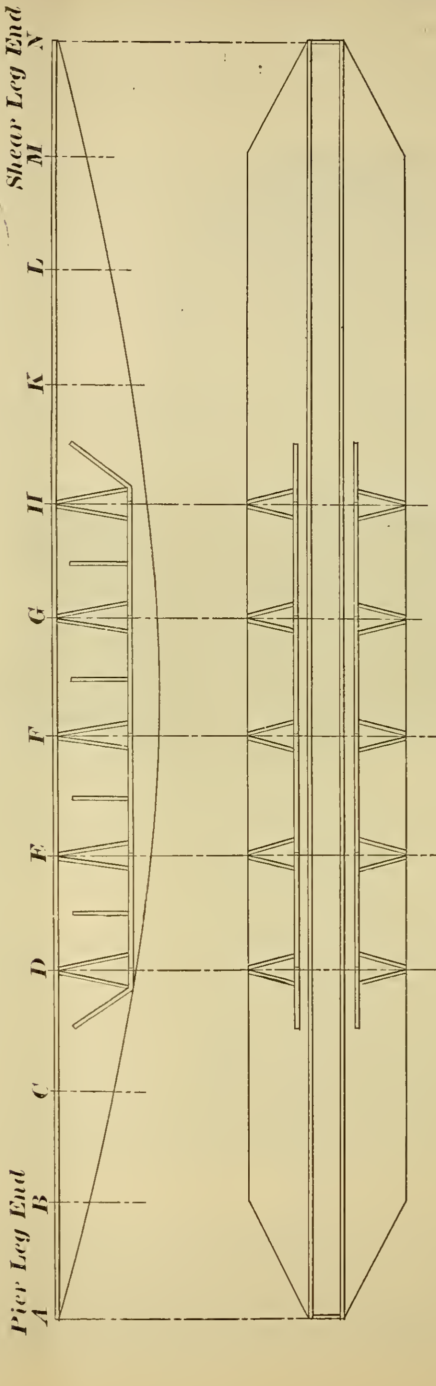


FIG. 8. SHOVEL BUCKET.

"racking ropes," of which, after also passing through the system of deflecting sheaves, one leads to one end of the bridge, around a sheave and back to the trolley, and the other to the other end of the bridge and back to the trolley. These ropes are also double. By this means the trolley, with its suspended load, may be rapidly moved to any point between the ends of the bridge. The speed of hoisting a 10-ton bucket of ore, or a total weight of about 13 tons, is from 250 to 300 feet per minute, and the speed of racking is from 800 to 900 feet per minute.

The bucket can be dumped either in one of the bins which support the bridge or on the stock piles on either side of and between the bins, by means of a simple dumping device, consisting of a piece of heavy gas pipe suspended from the truss by wire ropes,



Plan No. 3. Dumping Device. Furnaces 1 and 2.

like a trapeze. This gas pipe can be placed at any point and at such a height that, as the bucket reaches it, it trips a latch and the bucket dumps by gravity. To dump into a bin, the trolley is stopped directly over the desired point, and the bucket is lowered until a similar trapeze, properly placed, trips the latch. The construction of the bucket is such that, upon dumping, the entire contents fall vertically, without any side scattering whatever.

Another dumping device, applied to the bridge tramway at Furnaces Nos. 1 and 2, of the same plant, is shown in plan No. 3, and consists of a light framework between each truss and the adjacent stringer, extending along the central portion of the bridge. In this case the bucket is lifted at one end and brought to the

FIG. 9. SHOVEL BUCKET.

desired position under the framework. A slight raising of the bucket then brings a pair of spring latches in contact with the bottom of the framework, which thus releases them and the bucket dumps.

During the summer season the bins are ordinarily filled by buckets direct from the dumper, the excess of ore received over current requirements being deposited in the storage yard. When navigation is closed in the winter, ore still comes in from the lake docks, where great quantities are stored, but in the worst weather it becomes impracticable to draw from this source, and, no ore being received from outside, the bins are filled from the storage yard. This is accomplished by the use of a shovel bucket, shown in Figs. 8 and 9, which is attached to the block in place

of the detachable bail. This shovel bucket is lowered to the base of the pile of ore, and the trolley is moved forward until the hoisting rope leads back at an angle of about 45 degrees, when the trolley is held in position by a brake while the hoisting drum is started, with the result that the bucket fills with the ore as it drags up the pile, and is then carried to the bin and dumped.

The engine runs continuously and is not reversing, the several operations of digging, hoisting and racking, and the traveling of the structure, being accomplished by suitable clutches and brakes, manipulated by one operator, who is located in a small house above the engine house, whence he commands a view of all portions of the plant. The brake used for holding the trolley while digging is a powerful one, operated by hydraulic pressure, but it is not sensitive enough for the ordinary use of controlling the motion of the trolley while carrying a load. An auxiliary mechanism is therefore provided, whereby the same brake is operated by the foot, and the motion is easily controlled. An indicator in the operator's house, showing the position of the bucket at any moment, enables the operator to dump it at any desired point with accuracy.

The trolley, with its bucket, is capable of making twenty-five to thirty-five trips per hour, according to the distance which it has to travel, or an average of thirty trips per hour, giving a capacity of 3000 tons per day of 10 hours for each bridge tramway. Up to the present time, the highest record of buckets handled by one machine is 62 buckets in 105 minutes, equal to a rate of 254 buckets in 10 hours; but the greatest number handled in a full day of 10½ hours is 303, some time being lost in oiling, adjusting the dumping trapezes and changing the position of the bridge tramway for dumping in different parts of the yard.

Returning now to the car with loaded buckets, we have seen that it is stopped under the bridge tramway, which has already been placed over that portion of the bin or storage yard where it is desired to deposit the ore or limestone. The last bucket from the preceding car having been emptied while the car is moving away, it is returned and lowered to the vacant place in this car, and the detachable bail is transferred to the next full bucket, which is hoisted, racked, dumped and returned, and the process is repeated until the last bucket is taken, when the car moves away with three empty buckets, while another car with three full buckets takes its place.

One of the bins, upon which are laid the tracks which carry the bridge tramways, is seen in Fig. 10. These bins are parabolic in form, and are suspended from longitudinal plate girders,

which, in turn, are supported at frequent intervals by rigid frames consisting of heavy columns and transverse girders, the latter taking up the horizontal component of the pull from the suspension plates. The longitudinal girders which carry tracks are triangular in cross-section, having two webs meeting at the bottom, with a common bottom flange, and separated at the top by a distance equal to the gage of the track, but connected by a wide plate, which, with the connecting angles, constitutes the top flange. The outside web is so inclined as to make it tangent to the parabola, and extends below the bottom flange to provide a connection for the suspension plates. The inclination of the inside web from the

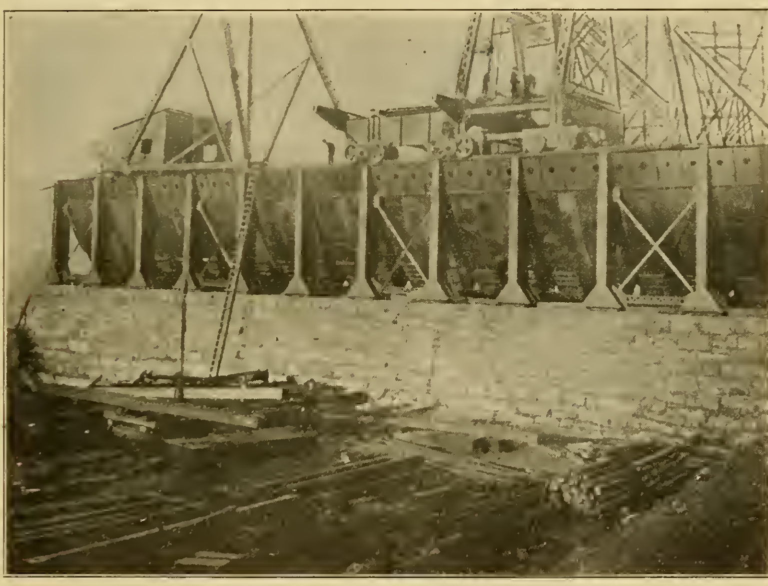


Fig. 10. Bin.

vertical is the same as that of the outside web. This construction forming a closed section, holes are provided in one web to permit of painting the interior. Vertical partitions are added at intervals, dividing the bins into a series of pockets, in order that the limestone and different kinds of ore may be kept separate. In each section, between any two columns, two chutes are provided at the bottom, one to deliver to the right and one to the left. These are closed by gates revolving about a horizontal axis, whose center is a short distance below the bottom of the bin. These gates are operated by steam power.

Below each bin, and at every pair of posts, is a cross-beam

supporting a suspended double track, on which travel electric locomotives, each with two larries. The tracks are so located that the chutes will deliver directly into the larries, and the latter are provided with scales, so that, by drawing successively from different pockets, mixtures of ore in exact proportions can be easily secured. An electric locomotive, with one larrie, is shown in Fig. 11. At the furnace end of each bin the suspended track stringers are extended over the pit into which the skips are lowered, and the larries, having been properly filled, are pushed by the locomotive to a position over a chute guiding to the skip, and are there emptied. Between the end of the bin and the skip is a transfer table, operated by a special electric motor, by means of which, if any accident should happen to a locomotive or larrie on one side, or if it should become necessary to repair a gate or its operating mechanism, the supplies could all be drawn from one side of the bin and transferred from one track to the other, so as to serve both skips. These bins are used only for the supplying of the various kinds of ore and limestone. The coke, which must be carried by the same skips, is brought in in cars on an elevated track, from which it is dumped into the coke bins, situated on each side of the skip pit, as shown on general plan No. 1. From these bins the coke is drawn off through gates into the side chutes leading to the skips. Two skips are used, running on an inclined double track, as shown in Fig. 2, from the bottom of the pit, in which they receive their loads, to the top of the furnace, where they are automatically dumped by means of a peculiar arrangement of tracks and wheels. The front wheels are of ordinary width, and follow the main track. The rear wheels are much wider, extending beyond the main track to such an extent that, at a point near the top of the furnace, where a second track is added outside the main track, these wheels will run on and follow the second track. This track continues in the same inclined plane in which lies that portion of the main track below the point referred to, insuring the continued upward motion of the rear end of the skip, while at that point the main track leaves this plane and follows a vertical curve, whose center is below the track, thereby leading the front wheels in toward the center of the furnace. The rear wheels having continued to rise, the skip is tipped toward the furnace and the contents are dumped into a large hopper. The hoisting mechanism being reversed, the skip descends while its mate rises, the weights of the skips counterbalancing each other, so that the power required is only that necessary to lift the load and overcome the friction.

At the bottom of the hopper is a cone, which distributes its contents with approximate equality, as the ore, limestone and coke pass through onto a small bell. When two skiploads have thus been deposited on the small bell, it is lowered and the distributed mass falls upon the large bell. Again two skiploads are deposited upon the small bell, and it is once more lowered. After the small bell has been raised again to its upper position, so as to form a seal for the gas, the large bell is lowered and the entire mass falls into the furnace, adding a well-distributed layer to those which have preceded it.

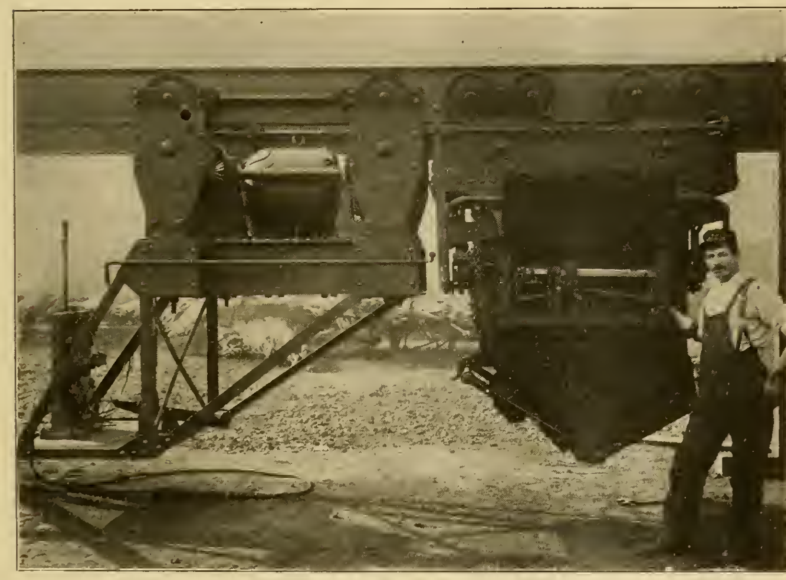
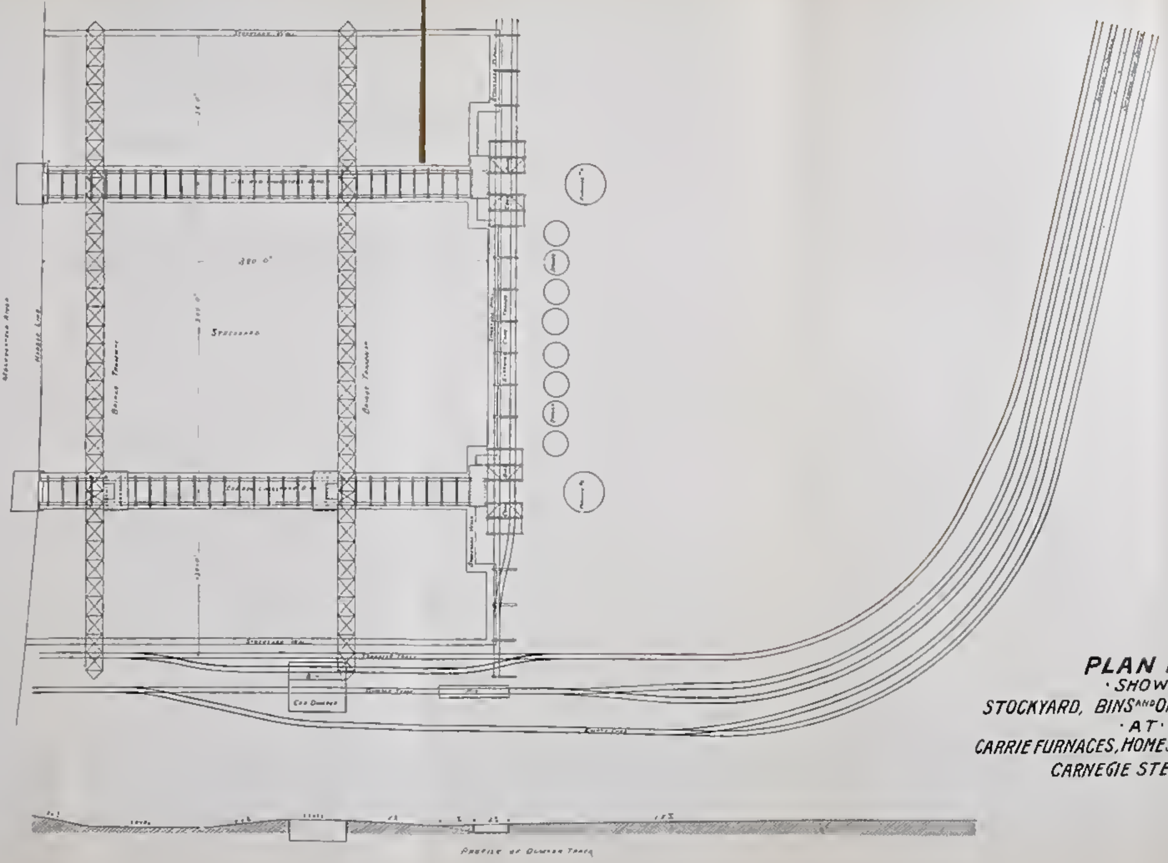


Fig. 11. Electric Locomotive and Larry.

This presents in outline the course of the raw materials as they pass from the cars, in which they reach the yard, to the interior of the furnace, all operations, after the cars are left by the locomotive on the dumper floor, being performed by electricity and controlled by the minimum number of human hands, only eighteen men being required to perform all the operations described for the two furnaces. As suggested at the beginning, it is in the great reduction of manual labor, effected by these appliances, that the economy of installing them at considerable cost is found, but it is an easy matter to show that, with this plant efficiently operated to its maximum capacity, a saving in the cost of production can be secured equal to from 40 to 50 cents per ton of pig iron, which, at the

rated capacity of the two furnaces of 1400 tons per day, amounts to an annual saving of from $200,000 to $250,000.

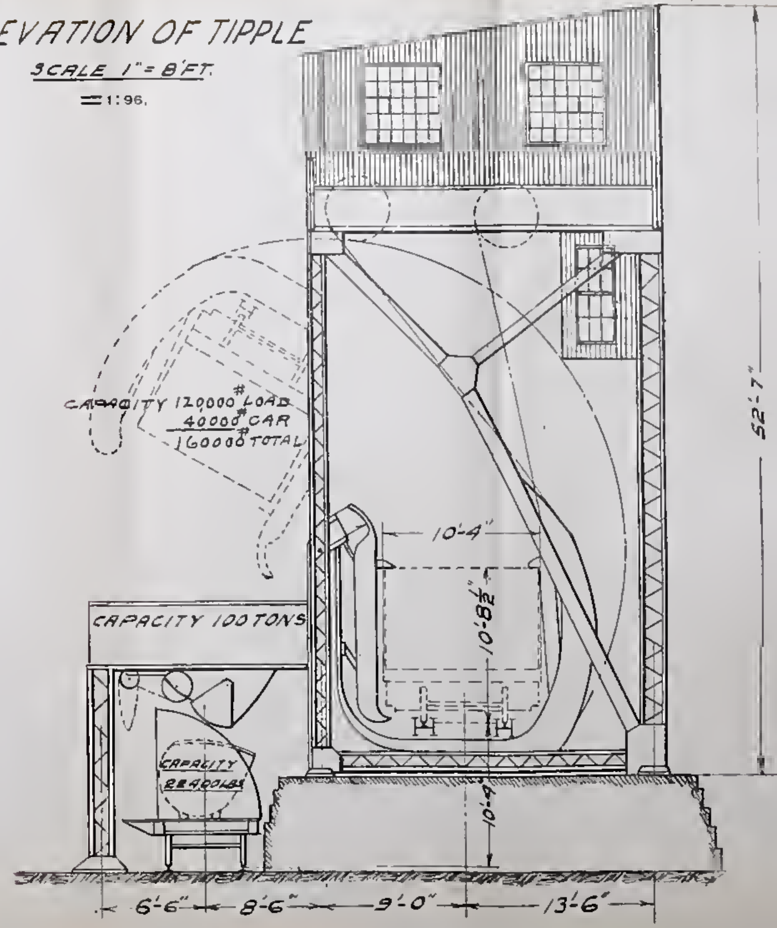
It is not strictly within the scope of this paper, but it may be of interest to note that the elevated structure at the left of Figs. 2 and 3 is the approach to the Union Railroad Company's bridge across the Monongahela River, built and used solely for transporting the molten metal in large ladles from these furnaces to the steel furnaces of the Homestead Works, on the other side of the river.



PLAN NO. I
· SHOWING ·
STOCKYARD, BINS AND ORE HANDLING TRACKS
· AT ·
CARRIE FURNACES, HOMESTEAD STEEL WORKS·
CARNEGIE STEEL CO.

ELEVATION OF TIPPLE

SCALE 1" = 8 FT.
= 1:96.




MAXIMUM LOAD ON EACH WHEEL

563'-1¾" OVER ALL OF SHEAVES
558'-0½" OVERALL OF TRACK STRINGERS
540-1" TOTAL TROLLEY TRAVEL
152'-0"
250'-3" SPAN
139'-9"
CAPACITY OF BUCKET 22400 LBS.
CLEARANCE LINE OF DUMPED BUCKET
PIER
SHEAR LEG
PLAN NO 2
SIDE ELEVATION
SCALE 1" = 20 FT.
= 1:240
CAPACITY PER 100 FT. 1560 TONS
CAPACITY PER 100 FT. 1550 TONS
AREA OF CROSS SECTION OF PILE 4000 SQ. FT.
AREA OF CROSS SECTION OF PILE 10000 SQ. FT.
AREA OF CROSS SECTION OF PILE 4000 SQ. FT.
CAPACITY 22400 LBS.
EL. 110.
EL. 100
EL. 102
239'-4"
21'-6"
130'-0"
260'-0"
130'-0"
541'-6"
40'-9"
36'-10"
MAXIMUM LOAD ON EACH WHEEL INCLUDING WIND 29,000 LBS.
MAXIMUM LOAD ON EACH WHEEL INCLUDING WIND 46,000 LBS.
MAXIMUM LOAD ON EACH WHEEL INCLUDING WIND 32,000 LBS.
MAXIMUM LOAD ON EACH WHEEL INCLUDING WIND 34,000 LBS.
MAXIMUM LOAD ON EACH WHEEL INCLUDING WIND 34,000 LBS.

THE BALTIMORE DRY DOCK OF THE WM. SKINNER & SONS SHIPBUILDING AND DRY DOCK COMPANY.

By James Ritchie, Member Civil Engineers' Club of Cleveland, Ohio.

[Read before the Club, October 8, 1901.*]

In February, 1899, the writer was requested to prepare plans, specifications and estimates of cost for a timber dry dock for the Wm. Skinner & Sons Company, of Baltimore. After the plans had been prepared it was thought better to construct the dock of concrete and masonry, and plans were made on that basis. Proposals were received for a concrete dock, but the company decided to construct the dock of timber, with a concrete and masonry entrance. The plans and specifications were modified to conform to this decision, and on June 29, 1899, a contract was awarded to the Delaware Construction Company, of Wilmington, for the construction of the dock and approaches, and that contract will be completed by November 1 of this year.

The accompanying drawings show the general plan, midship and longitudinal sections, section through masonry entrance and the plans and sections of the power house.

The principal dimensions of the dock are as follows: Length over all, 626 feet; length on keel blocks, 576 feet; distance from inner face of gate, when placed in outer grooves, to head of dock on keel blocks, 600 feet; width of entrance at bottom in clear, 60 feet $2\frac{5}{8}$ inches; width of entrance at top in clear, 80 feet $2\frac{5}{8}$ inches; width of basin on top, 125 feet; depth of water on inner sill at low tide, $22\frac{1}{2}$ feet.

Within the last three months, and after visiting the new dock at Newport News, it was decided to build at the head of the dock a pocket which will allow the bow of a vessel to extend 23 feet 4 inches beyond the original head of the dock, and will enable us to dock a vessel 600 feet long over all.

The location of the dock is such that it could not be wholly constructed within the limits of the existing shore line, as will be seen by examining the plan. In fact, the concrete and masonry of the entrance were constructed at a distance of about 208 feet from the shore, but still inside of the established harbor lines. This entrance had to be excavated to a depth of 36 feet below low water, and covered a space of 44 by 164 feet, requiring the above depth over the entire space. To accomplish this work and to provide a permanent protection for the same after the completion of the dock,

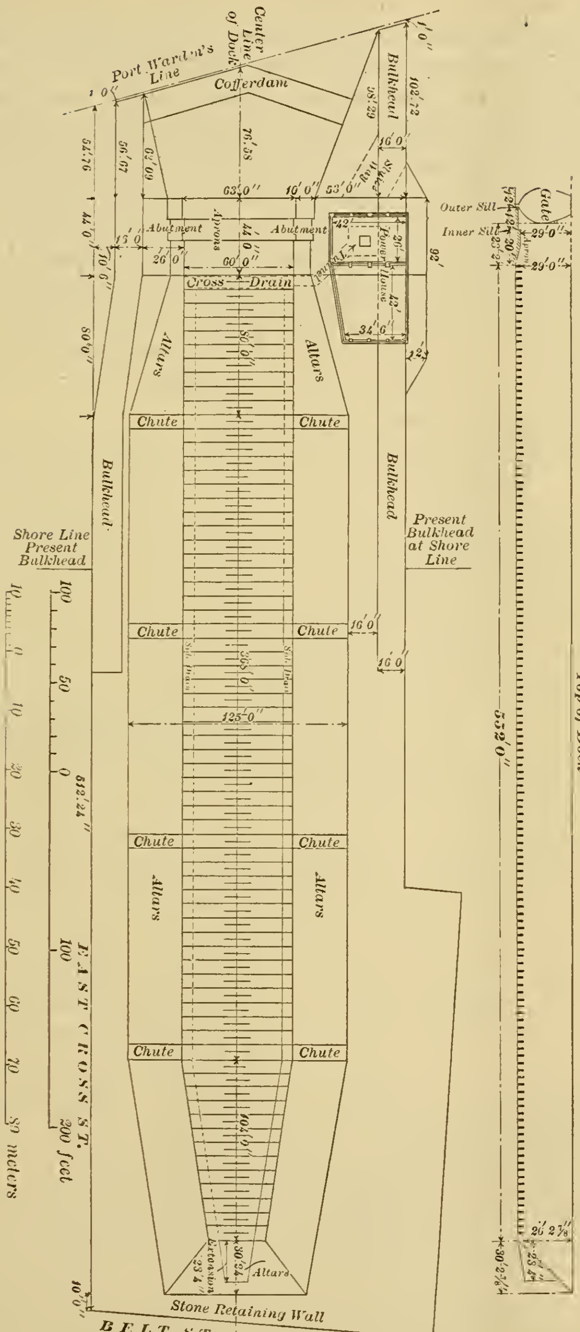
*Manuscript received October 21, 1901.—Secretary, Ass'n of Eng. Socs.

a bulkhead was constructed of 10 x 12-inch tongued and grooved sheet piling, from 34 to 48 feet in length, driven in two rows 16 feet apart, braced by guide piles, 12 x 12-inch timbers and $1\frac{3}{4}$-inch iron rods every 10 feet, the inside walls of these bulkheads being from 132 to 145 feet apart. On the south side of the dock, opposite the south abutment, a third row of sheet piling was driven outside of the bulkhead, and between the two outer rows the concrete wall of the power house was constructed.

The entire area of the dock was then dredged to the depth required for the dock bottom, and the entrance closed by a cofferdam of the same form as the protection bulkheads. The 16-foot space between the walls of the bulkheads and cofferdam was filled with clay, and the water in the dredged portion was pumped out. During the process of pumping out, braces were put in from side to side of the basin, supporting them on temporary piling, which effectually prevented the bulkheads from yielding to the outside pressure. Also, there were two rows of 10 x 12-inch tongued and grooved sheet piling driven across the dock, one at each end of the proposed excavation for the entrance masonry, and these two rows were braced together by heavy timbers. The end cofferdam was also braced with timbers to the outer of these cross-rows, and the inner row was braced to a line of piling in the inner basin, afterward used as a part of the supports for the dock door.

After the water was pumped out the bottom of the entrance excavation was finished to the required depth, and the work of concreting was commenced. The foundation soil was a hard white clay, of such firmness that the sheet piling had broomed up on the ends as if they had struck rock. Above this clay there was fine white sand, of variable depth and occurring in pockets, and this material caused us considerable trouble by reason of its water-bearing character. Above the sand was a stratum of red gravel, very hard and compact, in which some of the sheet piles had brought up, so that in some cases we had to excavate below the ends of the piling to secure our depth. By careful handling of the concreting, we overcame the difficulties caused by the water, and concreted the whole area up to the level of the under side of the apron masonry without serious trouble. In order to prevent leakage from the outside when the dock should be in service we excavated a trench 3 feet deep in the white clay clear across the entrance, and filled the same with concrete, to act as a cut-off wall.

The south abutment was designed to contain the pumping plant, and a tunnel to convey the water from the dock to the pumps was formed in the concrete. The tunnel was 6 feet wide and 6



PLAN AND SECTION.

feet high, and its roof was formed of concrete $10\frac{1}{2}$ feet thick, the upper surface of which formed the floor of the engine room. Iron beams 12 inches deep were set on the walls of the tunnel and imbedded in the roof, and the suction pipes of the pumps and foundation bolts of the engines were also built into the concrete. The suction pipes had flanges cast on them at intervals, projecting into the concrete, to serve as supports and to cut off seepage of water. At the distance of 3 feet below the floor and the same distance back from the face of the engine room walls a layer of Portland cement mortar was put in for the purpose of overcoming the porous nature of concrete and preventing leakage. As the walls were built up this layer of mortar, which was 3 inches thick, was carried with them to a point above high water mark, the floor of engine room being 16 feet below low water line.

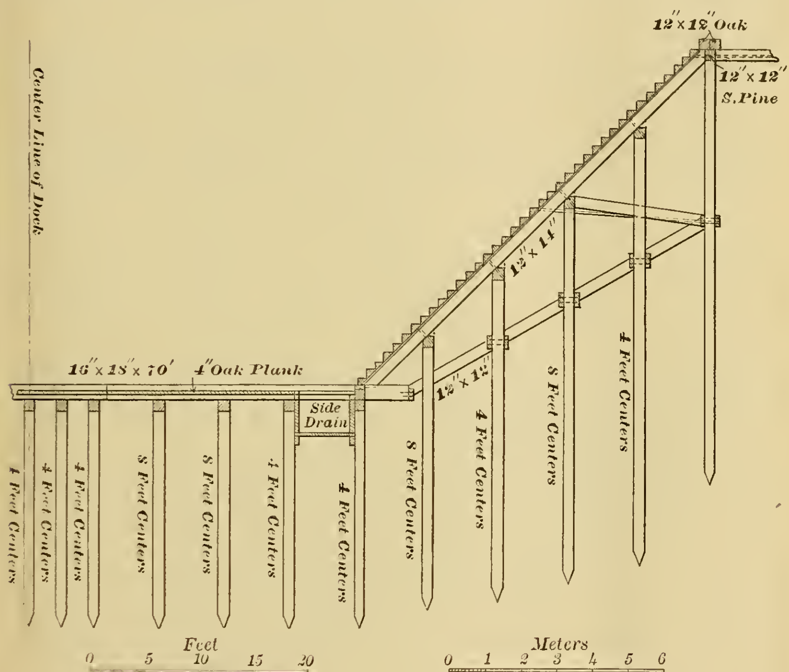
All of the concrete used on this work is made of one part of American Portland cement, two parts of sand and five parts of broken stone, and this mixture we found very satisfactory. The cement used was what is known as "Dragon," made in the Lehigh Valley, and each lot of one hundred barrels was tested for tensile strength after seven and after twenty-eight days' setting. Hot and cold pat tests were also made, both in air and water, and the results were such as to show a good quality of cement. We had considerable trouble in securing a good quality of sand, but, after repeated rejections, a very fair material was obtained. The broken stone was generally very good, being clean, uniform in size and of a good quality of granite.

The facing of the abutments and the floor of the aprons was of Port Deposit granite, and is a very fine piece of work. The sill stones are 6 feet thick, and weigh from 14 to 17 tons each. They rest upon the concrete base, which is from 8 to 10 feet in thickness. The apron floor is of granite, from 2 to 3 feet in thickness, according to location. The abutments are faced with granite in courses of 2 feet in thickness, the stretchers being not less than 6 x 4 feet and the headers 3 x 6 feet, which gives the walls a very massive appearance. All the stones are doweled together on the beds, and the outer sills are tied to the inner sills by steel bands bedded in the concrete base.

As soon as the concreting reached the floor level of the engine room, which is 10 feet above the floor of the dock, the Morris Machine Company, contractors for the pumps and engines, commenced to set the same in place and to put in the discharge pipes which go through the outer walls, and had to be concreted into place. There are three main pumps, each capable of discharging

35,000 gallons of water per minute, and one drainage pump, all being of the centrifugal type. The latter is for the purpose of taking care of the leakage of dock when same is in use. Each pump is operated by a vertical single high-pressure steam engine, and is furnished with gate valves in both the discharge and suction pipes. The pumps will discharge wholly below the level of the water in the harbor, and can thus be primed at any time by opening the valves in the discharge pipes.

The foundations of the boiler room consist of a bed of concrete 7 feet thick, supported upon a grillage floor which rests on piling.



Half Cross-section of Dock Midships.

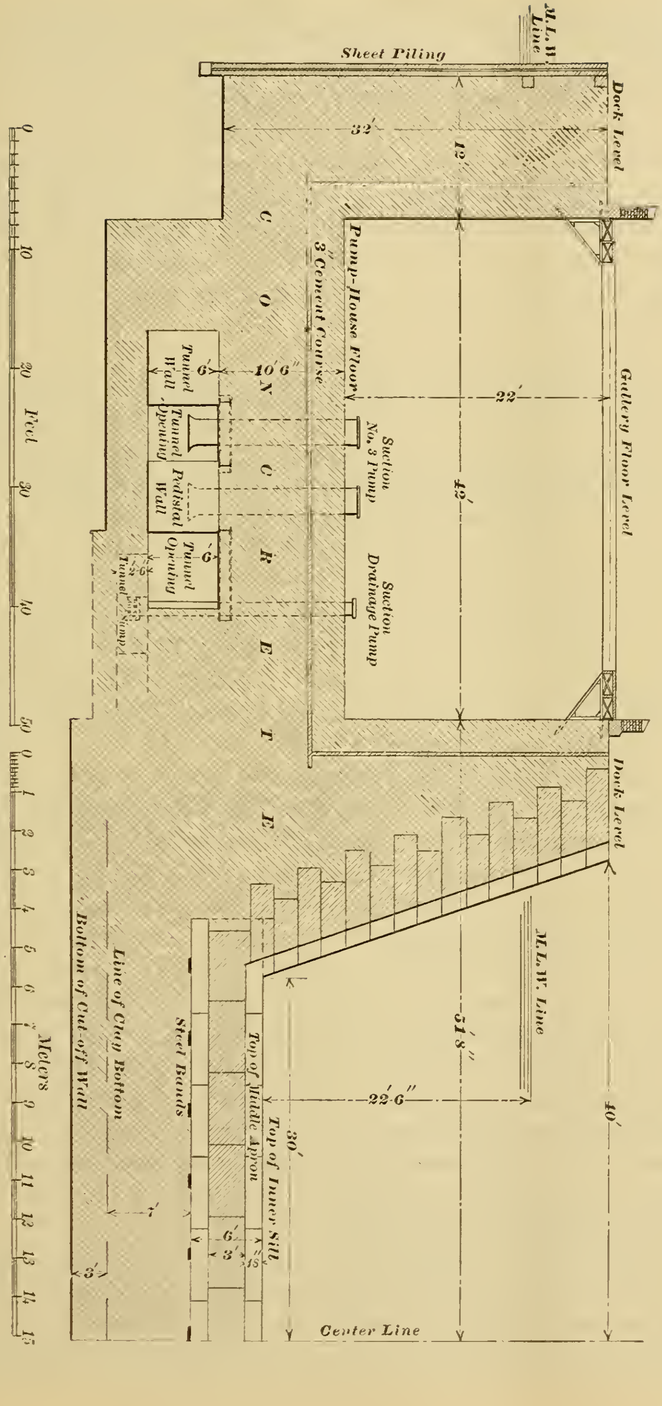
The concrete extends down below low water line, and in it there is formed an air duct for the forced draft. The boiler plant consists of a battery of three Heine water tube boilers of 350 horse power each, or a total of 1050 horse power. In addition to this battery there is an auxiliary tubular boiler for furnishing steam for the drainage pump and the pumps in the gate, as well as the engine that drives the air fan.

As soon as the pumps and boilers were in place the contractors erected the power house superstructure, which is a brick building

with an iron roof, and which will have a platform 4 feet wide around the engine room, with stairs leading down to the engine platforms.

The dry dock basin is constructed of piling and timber, as shown on the plans and cross-section. There are thirteen longitudinal rows of piles, capped with 12 x 12-inch timbers, drift bolted to the piles. Upon these caps are placed the transverse sills, securely boted to the caps. These consist of 16 x 18-inch Oregon fir timbers, placed 4 feet apart on centers. Every alternate timber is 70 feet long, the intermediates being 14 feet long. On these timbers are placed the keel blocks every 4 feet, and the slide or bilge blocks every 8 feet, for supporting the vessels when in dock. The floor is of oak plank 4 inches thick, spiked to supports which rest upon and are bolted to the longitudinal caps. The floor slopes from the center of dock to the sides, and at each side there is a longitudinal drain which empties into a cross-drain leading to the tunnel under the engine room. The slopes are formed of five rows of piles on each side of dock, capped with 12 x 12-inch timbers longitudinally of dock, and braced by 12 x 12-inch braces from ends of transverse timbers to waling pieces bolted to the rows of piles. The slope timbers are 12 x 14 inches every 8 feet, resting on and bolted to the caps and framed into the upper side of the main cross-timbers of floor. Another slope timber, 8 x 14 inches, is placed midway between the main slope timbers, and framed into a filler which runs between the main cross-timbers of floor. There are four chutes on each side of the dock, extending from top to bottom of the slopes, for the delivery of material into the bottom. These are 8 feet wide, and are made of 6-inch oak plank laid on the slope timbers, and having a combing on each side consisting of an 8 x 14-inch timber. The remainder of the side slopes are covered by altars or steps, having a rise and tread of 10 inches, the top being finished by an oak coping made of two pieces of 12 x 12-inch edge, bolted together; all the altars being spiked to the slope timbers, and the coping being drift bolted to the upper cap. The head of the dock has an extension, previously mentioned, made by setting in 10 x 12-inch sheet piling and bolting same to heavy timbers framed into the caps and floor timbers, and braced in every possible manner.

As the east line of the street was only 16 feet from the top of the dock at its head and 12 feet above same, it was thought best to concrete the slopes at the head of the dock and also the sides for a distance of about 60 feet from the head end, to prevent any possibility of the settlement of the outside earth. Also at the end of the dock on the north side, just inside of the entrance masonry, where



HALF CROSS-SECTION THROUGH ENTRANCE AND POWER HOUSE.

the top of slope approached very nearly to the inside wall of the protection bulkhead, we placed a solid wall of concrete. In all other parts of the slope the earth excavated from the bottom was filled in back of the altars as they were placed in position.

On September 25, 1901, the contractors finished cleaning up the dock and removed all temporary pumps and engines from the same, allowing the water to gradually flow in until the dock was filled, and then commenced to remove the end cofferdam and dredge out the entrance. This will be completed about October 20, and the gate will then be placed in position and the dock pumped out for a final test.

The gate is a steel caisson, made to set in the grooves of the masonry entrance, and to be sunk into position by filling its compartments with water. It is provided with six Ludlow gate valves for letting water into the dock, each valve being 36 inches in diameter, and with valves for filling and emptying the caisson. There is also an engine and pump for emptying the caisson, they being placed on the main deck. Steam will be furnished through hose connections from the auxiliary boiler in the power house.

A retaining wall of rubble masonry, 158 feet long, has been built to protect the street at the head end of the dock, giving a drive 12 feet wide around the head of the dock. The side street is protected by the sheet pile bulkhead driven along the street line at the commencement of the work.

On each side of the dock, and extending its entire length, is a water pipe, with hose connections between every chute, for use in washing out the dock. This pipe is connected to the supply pipe from the city mains, and also to the pumps in the power house, so that in any case a full supply of water for washing out or for fire protection can be furnished.

The keel blocks are placed at intervals of 4 feet on the center line of dock. They are 3½ feet high, being made of three pieces of 12 x 16-inch and one piece of 6 x 16-inch oak, bolted to the cross-timbers of floor. The slide or bilge blocks are placed every 8 feet, and arranged to be adjusted to the shape of the vessel, both by hinging the upper block and by sliding the entire block on the floor timber. Iron dogs, working in a rack on the floor timber, hold the blocks in place, and the dogs can be released by a pull of the chains used for moving the blocks back.

The work of construction was under the immediate charge of Mr. C. P. Ruple, resident engineer, who had a force of assistants on the work at all times, and the successful completion of the work without accident is largely due to their constant presence and care.

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THE LOWER MISSISSIPPI RIVER: PHYSICAL CHARACTERISTICS, METHODS OF IMPROVEMENT, CHARACTER AND VOLUME OF TRAFFIC.*

By J. A. OCKERSON, MEMBER OF THE ENGINEERS' CLUB OF ST. LOUIS.

A STREAM carrying the drainage of an area of 1,256,000 square miles, having 15,000 miles of navigable tributaries and which is itself 2500 miles in length, justifies the appellation of "Father of Waters." The Mississippi River, rising in Northern Minnesota, where its waters are ice-bound for nearly half the year, flows southward, gathering strength and volume on its way to the sea until it finally enters the Gulf of Mexico, where it washes the shores of semi-tropical Louisiana.

The regulation and control of a river of such magnitude involves problems which greatly tax the ingenuity and skill of man to solve. In its lower half the river oscillates in volume from a minimum flow of 65,000 cubic feet per second to a maximum of 2,000,000 cubic feet per second, and the oscillations in stage between extreme high and low water amount to 53 feet. About 1250 miles above its mouth the Missouri River enters, with its sediment-laden waters that are prolific in hindrances to navigation. This sediment and that derived from the erosion of the alluvial banks form the

*A portion of this paper was read before the International Engineering Congress at Glasgow, Scotland, September 4, 1901. It was later revised by the author and enlarged so as to cover the question of river transportation, and in this shape was read before the Engineers' Club of St. Louis, September 18, 1901. It was profusely illustrated with lantern slide views, some of which are reproduced here.

sand bars which develop during the falling stages of the river, and become at low stages formidable obstructions to navigation.

It will thus be seen that there are two distinct problems,—one involving the improvement of low water navigation and the other the prevention and control of destructive floods. Incidentally, the works executed for the latter have a direct influence on the former, by preventing a dispersion of the waters, and thus inducing a scouring effect in the bed, which enlarges its capacity. The lower half of the stream flows in an alluvial bed of its own formation, the banks of which are very easily eroded. This erosion takes place for the most part on falling stages. The banks, being composed of alternate layers of sand and silt, or clay, are disintegrated by the layers

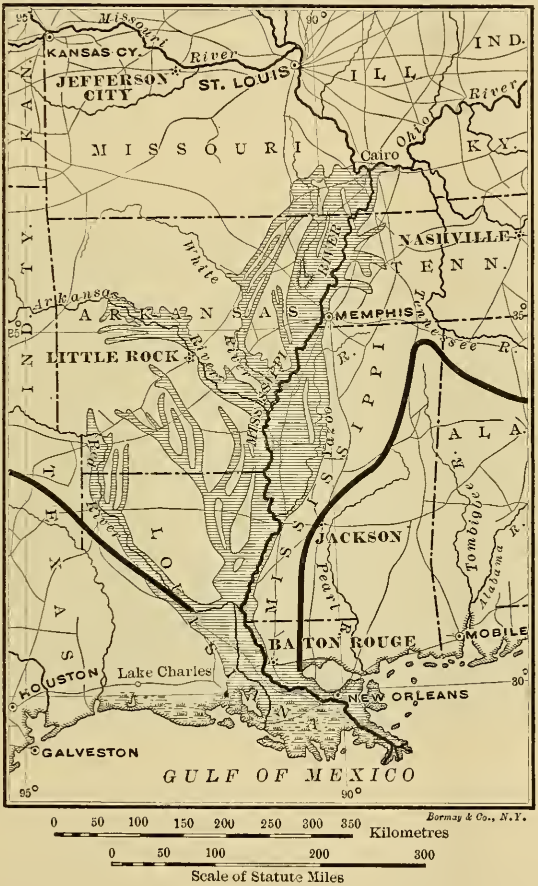
Burmay & Co., N.Y.

THE MISSISSIPPI RIVER WATERSHED.

of sand being washed out when the water in the saturated banks recedes toward the river as it falls. This leaves the clay unsupported and causes the banks to collapse in large masses, which slide into the river and then disintegrate from the force of the current. In the 885 miles of the river lying below the mouth of the Ohio River this erosion or caving amounts to an average of 9½ acres in area for each mile of river in a year, or a volume of about 1,003,579 cubic yards for each mile of river per year. The total annual amount of erosion for this reach equals 10 square miles 86 feet in depth.

In its natural condition the river, below the mouth of the Ohio, overflowed its banks at flood stages, which generally occur in the spring months. The destructive floods invariably come from the Ohio River and its tributaries; chief among which are the Tennessee and Cumberland Rivers, which drain a region in which the rainfall is exceptionally heavy. The alluvial basin subject to overflow

covers an area of about 30,000 square miles. It has a soil of remarkable fertility, which yields enormous crops of cotton and sugar cane. It is thus capable of sustaining a large population, adding very materially to the wealth of the country. This brief description of the physical conditions of the stream is essential to



Lower Alluvial Valley of the Mississippi River.
Showing area subject to overflow and lower limits of watershed.

an understanding of the problems relating to its improvement and the methods employed therein.

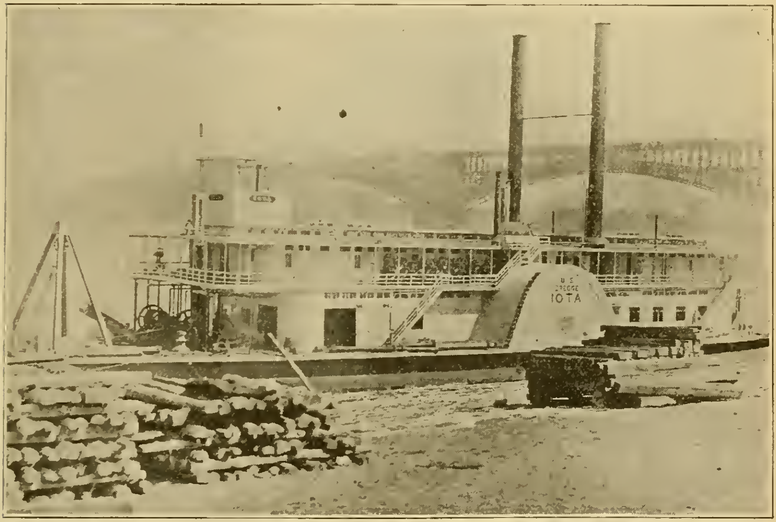
From St. Louis to Cairo, a distance of 180 miles, the work projected at present contemplates a channel 8 feet deep at low water and having a width of 2000 feet. The overflow stages are not of such frequent occurrences as to justify expensive embankments or levees to control the floods. The high stages occur in the months of May and June, while the low water season generally begins with

September, and often extends into the winter months. The system of improvement adopted for this reach consists in contracting the channel and closing the side chutes or channels by means of permeable dikes and hurdles. This requires that the banks must be held, which is done by means of revetment. Work is also done with hydraulic dredgers and temporary portable dikes, which are used to open channels through obstructing bars. On the completion of the contraction works now in progress, it is expected that a navigable channel of 8 feet in depth at low water will be readily maintained.

The Mississippi River Commission is charged with the survey and study of the physical conditions of the river from its source to the Gulf of Mexico. This survey consists of a chain of high-grade triangulation and a line of precise levels, which form the basis for a topographical survey covering a width of about a mile on either side of the river, and also for a hydrographic survey giving depths, slopes, volume of discharge, etc. Permanent marks or monuments are left at frequent intervals, and these serve as the initial points from which subsequent surveys are made for ascertaining changes occurring in the bed or banks of the river. The general survey, made in great detail, has been nearly completed; and about 2000 miles of the river have been mapped, and the maps have been published on a scale of 1 : 20,000.

The chief construction work of the commission has been confined to that portion of the Mississippi River lying between the mouth of the Ohio and New Orleans. The work has consisted of contracting the channel in wide places, revetment and dredging. A bill pending before the last Congress required that a thorough study shall be made with a view of ascertaining the feasibility and practicability of securing an ample waterway 14 feet in depth; the ultimate object being to secure a 14-foot channel from Lake Michigan to the Gulf of Mexico via the Illinois and Mississippi Rivers. The present law contemplates a channel not less than 9 feet in depth at the lowest stages of the river. Under natural conditions this depth prevails for an average period of about eight months in the year. The low water period generally ranges from the middle of August to December. This is, however, the period when the grain crops are moving and good navigation is most urgently needed. As the permanent improvement of a stream of such great length will necessarily require a long period of time, temporary expedients for the relief of navigation must be used, for which purpose hydraulic dredges of large capacity have been constructed. An experimental dredge was first constructed and worked for a period of over two

years, for the purpose of ascertaining whether dredging in a stream where such enormous quantities of material are continually moved along the bed by the current could give any beneficial results, and also to learn by experience how to maneuver and operate a dredge and discharge the material in strong currents. These experiments and work done since then have fully established the fact that a powerful hydraulic dredge can open an ample navigable channel through an obstructing sand bar and maintain it at a cost fully justifying the expense. There is now in the service of the commission a fleet of eight dredges, with a combined working capacity of over 10,000 cubic yards per hour.



U. S. Dredge "Iota."

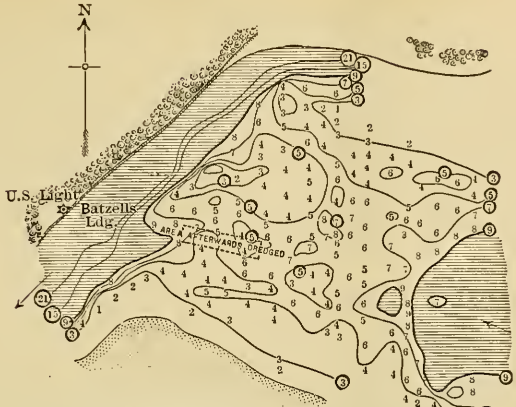
A description of one of the later type of dredges now under construction will give a good general idea of what is considered essential to a good dredge for work in a stream where the material to be moved is river sand. This type of dredge is provided with propelling power operating two side wheels. The hull is of steel, and ample cabin accommodation for machinery and crew is provided. The general dimensions are as follows: Length, molded, 192 feet; width, molded, 44 feet; depth, molded, 7 feet; maximum width over wheels, 70 feet; suction well at bow, 25 x 33 feet; working draft, 4 feet; cabin, 44 x 130 feet; diameter of centrifugal pump, 75 inches; suction and discharge pipes, 32 inches diameter; length of discharge pipe, 500 feet; main engine (tandem compound), 16 and 26 x 20 inches; and seven boilers, with four 11-inch flues, 44

inches in diameter and 30 feet long. The capacity of the dredge is 1000 cubic yards of sand per hour, delivered through 1000 feet of discharge pipe at a pump speed of 160 revolutions per minute. (See illustration of sand pump dredge.)

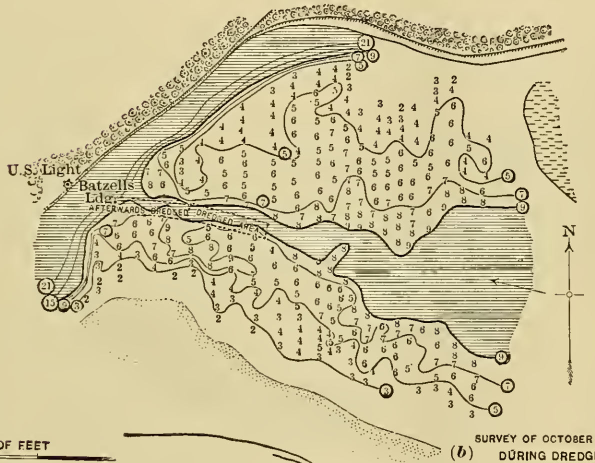
The sand pump has a suction on each side of the pump casing, and the discharge leaves the casing from the lower side and follows along a pipe laid on the lower beams of the hull to the stern, where it is connected with a floating pipe line. This floating discharge pipe is carried on pontoons in lengths of 100 feet, coupled together with flexible joints of rubber, so as to discharge outside of the channel. The discharge pipe line can be deflected by means of shifting the pontoons, and also by the use of a baffle plate at the end of the line. The pump runner, 75 inches in diameter, has five blades, and is keyed upon a steel shaft. The blades are provided with removable wearing plates $1\frac{3}{4}$ inches thick. The casing is of cast iron. The intake of the suction is in two parts, each $11\frac{1}{2}$ feet long b $8\frac{1}{2}$ inches deep. These suction heads are brought down to a section 22 inches square, and enter the hull by means of radial joints, which admit of raising and lowering the suctions at will. This motion is effected by wire ropes passing over sheaves, and operated by suitable winding engines. The material at the suction intake is loosened by water jets from twelve 2-inch nozzles working under a pressure of 60 to 120 pounds per square inch by means of a horizontal duplex compound plunger pump. The main engines are horizontal condensing engines of the tandem compound type of the dimensions given above. The boilers are of the Mississippi River type, bituminous coal being used as fuel. The dredge is provided with an electric light plant, refrigerating plant and steam steering gear. Ample accommodation is provided for quarters and for maintaining a double crew. A well-equipped machine shop provides facilities for making ordinary repairs.

When in operation, the dredge is manipulated by two wire cables 1 inch in diameter and 1200 feet long, one end being attached to hauling drums 48 inches in diameter and the other to hollow iron piling or mushroom anchors securely placed in the bed of the river. With the cables all paid out, the dredge is at the lower side of the sand bar to be cut through, and it is pulled up-stream at a speed varying with the depth of the cut and character of material. For depths of 5 feet, the rate of movement ranges from about 90 to 150 feet per hour, or sometimes even as high as 200 feet of cut per hour. After one cut is finished, the hauling cables are shifted; the dredge is again dropped back to the lower edge of the bar, and another cut is made along the side of the first cut. This process is repeated until

SUCCESSIVE CONDITIONS—(*a*), (*b*), (*c*)—OF CHEROKEE CROSSING, SHOWING RESULTS OF DRAINAGE.



(*a*) SURVEY OF SEPTEMBER 1, 1899.
NINE DAYS BEFORE DREDGING.



SURVEY OF OCTOBER 2, 1899.
(*b*) DURING DREDGING.

(*c*) SURVEY OF DECEMBER 14-15 1899.
THIRTY-NINE DAYS AFTER FINAL DREDGING

sufficient width has been obtained. After the first cut has been opened, the current is an active agent in assisting the development of a channel, provided the cut has been properly located with reference to the natural direction of flow; otherwise the artificial cut may be filled as fast as it is opened by the material which is moved along by the current. Last year a 10-foot channel was maintained throughout the low water season.

Where the dredged cuts are properly located, a satisfactory channel can be readily opened; and experience shows that when

CENTRIFUGAL PUMP OF U. S. DREDGE "DELTA."

once opened the channel will maintain itself until there is considerable fluctuation in stage, such as to change the direction of flow of the thread of the current. Such a dredge is operated at a total cost of about $100 per day of twenty-four hours.

REVETMENT AND CONTRACTION WORKS.

In a stream flowing through a bed of its own formation the banks are naturally very easily eroded, and a lateral movement in one direction or the other is continually in progress. Any permanent improvement of navigation requires the banks to be made stable to prevent the flanking of the channel works, and to stop the contribution of eroded material which builds up the obstructing

bars. Active bank erosion is confined to the concave sides of the bends in the river, where the thalweg lies close to the bank. These banks are sometimes 50 feet in height above low water, and extend down below for an equal depth. This gives a steep bank about 100 feet high, which must be protected in such a way as to prevent its erosion and disintegration, a very difficult and expensive work. There is no rock near at hand for use as ballast or paving, and it has to be brought from quarries several hundred miles away. The willows used for covering the bank below the low water line grow in profusion along the battures, but even the supply of willows would be severely taxed to meet the demands of a general system of bank revetment. The method now in vogue for holding the banks consists of a covering of fascine-willow mats ballasted with stone and usually 300 feet in width, extending from the low water line out into the stream. These mats are built and sunk in lengths of about 1000 feet. The only limit to the length is that fixed by the strength of the head lines which hold the floating mat in place during construction. With a strong current and large accumulations of drift, it is often difficult to hold a very long mat.

In the construction of a mat the first step is to secure the mooring barges end to end at right angles to the shore, and located at the up-stream end of the work. They are firmly fastened together, and cables reaching secure fastenings on shore hold them firmly in position. The heading for the mat is then made of a bundle of strong hardwood poles 5 to 8 inches in diameter, and is secured along the down-stream side of the mooring barges to which it is suspended. It is further secured by six or eight wire cables, an inch or more in diameter, passing under the mooring barges and leading to strong fastenings on shore. To obtain additional strength, a second heading is placed in the mat about 10 feet below the first one and securely fastened to it. Two mat barges, end to end, are dropped in below and parallel to the mooring barges, to which they are attached by three cables so arranged that the mat barges can be readily dropped down-stream as the mat is built. These barges are built with inclined ways on which the mat is constructed, and are provided with reels for holding the sewing cables and wire strands, all spaced at the proper intervals. Willow poles are next placed in position at the top of the incline and normal to the shore, and a fascine 12 inches thick and 300 feet long, or the full width of the mat, is constructed. The willows used range from 1 to 4 inches in diameter at the butts, and the entire length, including the bushy tops, is made use of. (See illustration.) Galvanized wire cables $\frac{5}{16}$ of an inch in diameter, spaced about 8 feet apart, are

attached to the heading, and run the whole length of the mat along its underside. The fascines are drawn close up to the heading, and are fastened together by a $\frac{1}{4}$-inch galavanized wire strand, which passes around each fascine, and also the longitudinal cables which are the mainstays of the mat. The weaving strand and bottom cables are clamped together at frequent intervals by staples driven into the large willows. As the matways become filled and the mat develops, the mat barges are dropped away; and this process is repeated until sufficient length has been made. Rows of large willow poles are placed on top and lengthwise of the mat at intervals

MAT WEAVING.
Showing construction of mat and the mat barges.

of about 16 feet, and are securely fastened in place. These poles perform the double function of strengthening the mat and preventing the loose rock ballast from rolling off. The channel edge of the mat is further strengthened with a $\frac{1}{2}$-inch galvanized steel wire cable having a breaking strength of 9 tons. This is clamped to the weaving cable on top of the mat at intervals of 10 feet, the upper end being secured to the heading. Where great strength is required, similar top cables are placed at intervals of 8 to 16 feet, according to the necessities of the case. A mat of the character described can be made at a rate of about 10 lineal feet per hour. When completed, the mat floats on the surface with one side resting against the river bank, the whole being held in place by the mooring lines. (See illustration.)

The next step is to sink the mat to the bottom. First a uniform distribution of stone is made all over the mat and of sufficient quan-

tity to barely allow the mat to float. Barges loaded with ballast stone are then brought to the head of the mat, and sufficient stone is placed thereon to sink it when the lines to the mooring barges are slackened off. The cables to the shore still hold it from moving down-stream. The head of the mat being on the bottom and the balance still afloat, the stone barges are dropped in below the mooring barges and parallel to them, and so connected that they can be floated down as the mat sinks. A large force of men then throw off the stone onto the mat, and as it sinks the barges float down over it, delivering the stone ballast uniformly until the whole rests securely on the bottom. The head cables, which are provided with special toggles for the purpose, are then removed and the subaqueous portion of the bank is secured by the ballasted mat. The final sinking of a mat 1000 feet long is accomplished in about an hour.

The form of mat described is found to serve the purpose very well, the weakest point being the wire fastenings, which in the course of time corrode and break. When once in place, the ballasted mat filled with sediment will remain under ordinary conditions even without fastenings. To obviate the defects incident to corrosion, experiments are being made with silicon bronze and other wires and different wire coatings.

The following materials are used per 100 square feet of mat: Willow brush, 1.639 cords; poles, 0.053 cord; steel wire, 4.861 pound; silicon bronze, etc., wire, 0.546 pound; wire strand, 10.965 pounds; clamps or staples, 1.500, and stone, 0.625 ton.

Another form of mat, called a crib mat, is used with good results where the plant is limited, and it also has the advantage of eliminating the use of wire and wire strand. These mats are constructed on temporary ways built on the bank near where the willows are cut. The dimensions are usually 100 x 150 feet and about 1 foot thick, but the mat may be of any suitable size or thickness. A bottom frame of sawed lumber is first laid on the ways, consisting of 2 x 4-inch pieces laid in pairs at intervals of 10 feet. Upright posts or binders are placed between the pairs of scantling at intervals of 5 feet, and are secured to them by wooden pins. The first layer of willows is next laid on and fastened with spikes across the frames, or at right angles to the river; a second layer is laid at right angles to the first, and a third layer parallel to the bottom layer. The whole is then firmly compressed by a special device, and a top frame similar to the lower one is put in place and securely pinned to the uprights. On top and across these top frames poles are fastened to stiffen the mat while being handled and to hold the ballast in

sinking. Each mat as completed is launched into the river, and when a sufficient number have been constructed they are bound together and towed by a tug or towboat to the point required. They can be bound together to form a long mat, or they can be sunk separately. The mat costs three cents per square foot afloat and six cents in place, and requires 12 pounds of stone per square foot to sink it.

After the sub-aqueous portion of the bank has been securely protected, the upper part of the bank is graded to a slope of 3 to 1 by a hydraulic grader, and the graded surface is paved with stone

Position of Mat Ready for Sinking.
Showing mooring barges and suspension lines holding mat up. Showing also the upper bank revetment or paving.

to a thickness of about 10 inches. This paving is carried up to within 10 feet of the top of the bank and sometimes is carried right up.

Where the ballast stone is very far from the work, artificial stone of cement and river gravel, which is usually near at hand in abundance, is made use of. German Portland cement is used in the proportion of 1 cement to 13 of sand and gravel. The mixer and its machinery is carried on a tramway laid on the gravel bar where the material is abundant, and a series of molds are placed on the ground along the tram. The blocks are made 7 inches thick, 12 inches deep and 6 feet long, and after hardening are broken into

sizes to suit. This artificial stone weighs about 140 pounds per cubic foot. A small plant will make about 160 tons per day at a cost of about $1.40 per cubic yard, as against $2 or more for the stone in some localities.

Experiments are being made with upper bank paving of concrete 4 inches thick laid *in situ*. Brick is also being tried for ballast and paving.

The average cost of a complete bank revetment, with a subaqueous mat 300 feet wide and upper bank graded and paved, is $27 per running foot of bank.

In some cases spur dikes or buttresses, spaced 450 feet apart, have been used to hold high banks and check the erosion, constructed of willows and stone built up in layers on a broad foundation mat. In some places these have failed by scour taking place behind them, as the above-water bank is left unprotected. Such spurs properly spaced would doubtless be successful and perhaps more economical than the standard continuous revetment. The closure of chutes or side channels is effected by means of brush and stone dams and pile dikes built to a height somewhat above low water.

LEVEES.

The alluvial basins below the mouth of the Ohio, which are subject to overflow, cover an area of about 30,000 square miles. At high stages these lands, under natural conditions, are flooded to depths varying from a few inches to 15 feet, or even more. Originally they were densely wooded, but the extraordinary fertility of the soil attracted the agriculturist, who settled there and cleared up the lands at the risk of being overwhelmed by the floods. Under such conditions only the very highest of the lands, which always lie near the river banks, could be utilized, and most of the land was left in its wild state until the inhabitants undertook to build barriers to keep out the annual floods. In this way the levee system began, and so long as it was confined to isolated districts, leaving the major portion of the basins still open to the floods, the levees required were of small dimensions.

When the improvement of the river began, it soon became apparent that it was important to confine the waters as far as practicable to the same general channel lines at both low and high stages. This meant that the floods must be confined throughout the whole length of the alluvial valley. To restrain all the enormous volume of water necessarily required much higher and stronger levees than had been found sufficient to protect isolated patches of land. As was expected, the river in flood, confined between levees a mile or

two apart, reached a plane considerably higher than when it was allowed to spread unimpeded over the wide expanse of basins. While the cause seemed quite apparent, many people attributed the rise in the flood plane between the levees to a filling up of the bed of the stream. This led to an extended investigation by the author, extending over several hundred miles of river, the conclusion arrived at being that there had been no very decided change in the bed; but, on the whole, the evidence pointed to a lowering of the bed. This view was further substantiated by the fact that the low

Caving Bank, Caruthersville, Mo.

water plane was very materially lower than it was prior to the completion of the levee system, although the depth and volume was equal to those of former years.

Prior to 1882 the construction of levees was confined to the several States and to private landowners. In that year there occurred one of the greatest floods known, and it became apparent that the aid of the general government was essential to adequate protection. Appropriations of funds were made, and since that time the Government has spent about $16,000,000 in levee construction, while the several States have spent about double that sum. The total length of levee lines below the mouth of the Ohio is about

1450 miles, but they still lack much to bring them up to the dimensions and height deemed necessary for safety.

The ordinary standard levee is built with a crown of 8 feet and side slopes of 3 to 1. The crown and sides are sodded with a very tenacious grass, known as Bermuda grass. Where the levee exceeds a height of 11 feet it is reinforced on the land side with a banquette of earth, which reaches a height of 8 feet below the top of the levee. The crown of the banquette is 20 feet in width, and has a slope, for drainage purposes, of 10 to 1, the side slope being 4 to 1. These dimensions of both levee and banquette are increased if the foundation is bad or the material is not good. In some

WAVE WASH AT BASE OF LEVEE.

places the only material available is a very sandy soil, and in such cases a very large section is required. The use of levees as roadways is strictly prohibited.

On approaching the lower end of the levee system, the floods sometimes continue to stand far up on the levees for several months, which tries them very severely, as they become saturated and easily abraded by wave wash from wind or passing steamers. To prevent the wave wash, a plank revetment is fixed a short distance from the levee. After a levee becomes thoroughly saturated with water, a collapse, with its destructive effects, may occur. Such breaks in the levees are called crevasses. When once formed, they continue to increase in width, and the rushing flood plays havoc with every-

thing in its wake. Houses, fences and even the soil itself are torn up, and great damage is done. When a break occurs, but little can be done beyond holding the broken ends, so as to save as much of the levee as possible. So far efforts at closing a break have not been very successful, and are always attended with enormous expense. Bank erosion is one of the most active and formidable agents in the destruction of levees. A considerable length of completed line often caves into the river, necessitating the construction

Water Rushing through a Crevasse or Break in the Levee.

of a new line farther back and connecting with the stable ends of the old line.

The above brief general description of the chief works carried on for the improvement of the Mississippi River will give a fair idea of what is being done. Anything like a detailed account of works of such great magnitude would require volumes, and they have only been touched upon here and there in this paper. It is hoped, however, that it may be of some interest and value.

TRAFFIC ON THE MISSISSIPPI RIVER.

It is a well-established fact that waterways are the only satisfactory regulators of freight rates, and that they have brought about in a natural and effective way that control of rates which

has long been sought through legal enactments with indifferent success. A brief glance at the enormous cargoes carried will readily show why this must be so.

A single cargo of coal, amounting to between 40,000 and 50,000 tons, is carried from Louisville to New Orleans via the Ohio and Mississippi Rivers, a distance of 1400 miles, at a cost of about 10 cents per ton. Wheat in bulk is to-day carried from St. Louis to New Orleans, a distance of 1200 miles, and placed on shipboard at a rate of $4\frac{1}{4}$ cents per bushel. Cargoes of 375,000 bushels, or 375 carloads, have been taken by a single towboat and its barges. A stern-wheel boat has carried at one time 9226 bales of cotton and a large amount of cottonseed. This load borne on a single hull would fill 369 ordinary freight cars.

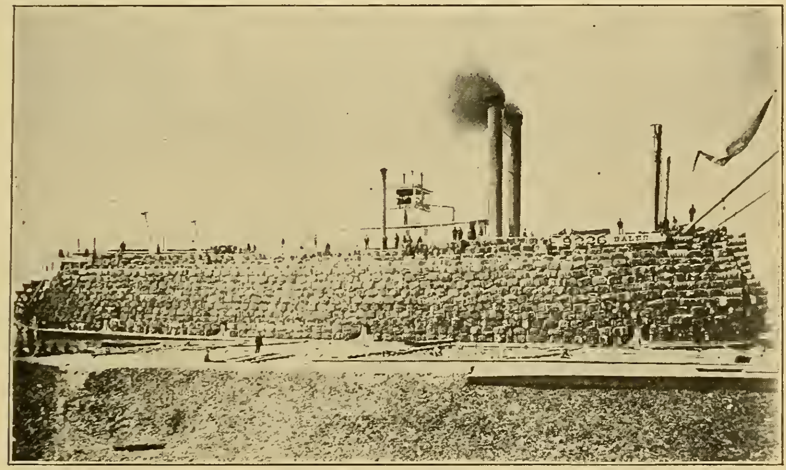
Add to these the fact that the capacity of a great waterway is practically unlimited, and is open to all who choose to use it, and its great value to producers and consumers becomes at once apparent.

In this connection it will perhaps be of some interest to examine, as far as practicable, the condition of river traffic in the past. Efforts have been made from time to time to ascertain the volume of traffic on the Mississippi River for a period of years, and reaching back to the time when traffic by boat was said to be at its zenith. All such efforts have practically failed, owing to the fact that reports of receipts and shipments have not been exacted from steamboat owners or shippers. An accurate record covering the total volume of river traffic for a long period of years is essential to a satisfactory analysis of the changes which are commonly supposed to have taken place in both volume and character of that traffic. Fortunately, considerable scattering data can, by much tedious labor, be brought together for convenient use. Much of the data herein was obtained from the records of the St. Louis Merchants' Exchange.

No reliable record of the tonnage volume of river traffic at St. Louis prior to 1871 could be found. The record of boat arrivals is, however, complete. The total volume of grain shipments has been tabulated in connection with the shipments by river to show the percentage carried by the latter. The freight rates are given to show not only the great reduction in the rates from year to year, but the relation between rates on grain by river and by rail. This covers the rate from St. Louis to Liverpool via New York, and by the river route and New Orleans. All of these data are also shown graphically in a way that gives at a glance the salient points in each of the elements coming under this investigation.

During the Civil War, the traffic was diverted to the east-and-west lines by rail or by the Great Lakes to the seaboard, and the lower river was only utilized for the transportation of war materials and supplies. When the Mississippi River was again opened to traffic it was still handicapped by the shallow water at the mouth of the river, which prevented the standard seagoing craft from entering the river. Small craft of not over 15-foot draft were the rule.

While the freight on grain by the river to Liverpool via New Orleans was much less than via New York by rail or by the lake route, the shipments were comparatively small, owing to the shallow water at the passes and to the general belief that grain in



STEAMER "HENRY FRANK."
Loaded with 9226 bales of cotton; 369 carloads.

transit through the warm climate would be badly injured. Actual tests soon showed that no injury resulted in transit from climatic conditions. The obstructions at the mouth of the river were successfully eliminated, and the producers of the Mississippi Valley reaped very material benefits from the reduction in rates on export grain.

Prior to 1868 the river traffic was confined to individual steamboats carrying package freight and grain in sacks. In 1867 a barge line was organized having for its object the carrying of bulk grain and other heavy commodities on several barges propelled by a single towboat. This resulted in a large reduction in expense, and a consequent reduction in rates. Grain was loaded in barges at Peoria, on the Illinois River, at St. Paul and Rock Island, on the

upper Mississippi River, and taken direct to New Orleans, where it was transferred to ships for New York or foreign ports. These earlier barges had a capacity of about 300 tons each, and ten barges were taken by one towboat.

Owing to the small ships plying to New Orleans, much of the grain was taken to New York and there loaded into larger vessels. Even this was found to be cheaper than the routes by rail to New York.

The opening of the passes to vessels of 26-foot draft in 1879 gave a new impetus to the Southern grain route, which in 1880 carried one-third of the total shipments from St. Louis, and reached a total of over 15,500,000 bushels from that port alone. The development of the barge traffic on the Mississippi River established the fact, beyond a possibility of a doubt, that this is by far the cheapest form of transportation known to-day. By its proper development and use, there will result a movement of bulky freights in the raw material that will bring new products to a profitable market that would otherwise remain inert.

BOATS AND VOLUME OF BUSINESS.

The average annual number of arrivals of boats at St. Louis for five years, 1865 to 1869, inclusive, was 3790, while for the years 1896 to 1900, inclusive, the average annual number of arrivals was 2590. This shows a decrease of 31.6 per cent. in number; the difference in tonnage would doubtless be much less than this. The greatest number of boats arrived during a year was 4692, in the year 1880, and the least number was 2217, in 1900. The total number of ships passing through the jetties at the mouth of the river in 1900 was 3005.

The average volume of river business at St. Louis per annum, 1871 to 1875, inclusive, was 1,531,822 tons. The average for a corresponding number of years, 1896 to 1900, inclusive, is 924,756 tons, a decrease of 39 per cent. The largest volume of traffic occurred in 1880, and the smallest in 1899. The large volume of traffic followed closely the completion of the jetties at the mouth of the river.

An inspection of the stages and the traffic curves shows plainly that other causes than low water operate to influence the volume of river traffic. The general conditions of trade, the foreign demand, the crop conditions at home and abroad, all directly affect the volume of traffic both by river and rail, and account largely for the fluctuations that appear from year to year. In 1867 it was announced that "boating interests generally are dull and unprofitable."

The theory that there is a progressive deterioration in the navigability of the river, which is responsible for the decline in the volume of traffic, is not founded on fact. A search of the early records reveals many accounts of "4 feet and 5 feet scant to Cairo," and at least one of 3 feet. Such small depths are now unknown. There are also numerous records of less than 4 feet in the Missouri River and "2½ to 3 feet" in the Illinois River.

The volume of traffic in 1896 exceeded that of each of the five preceding years, and was greater than that of three other prior years, 1877, 1885 and 1888, so that, while the later years show less

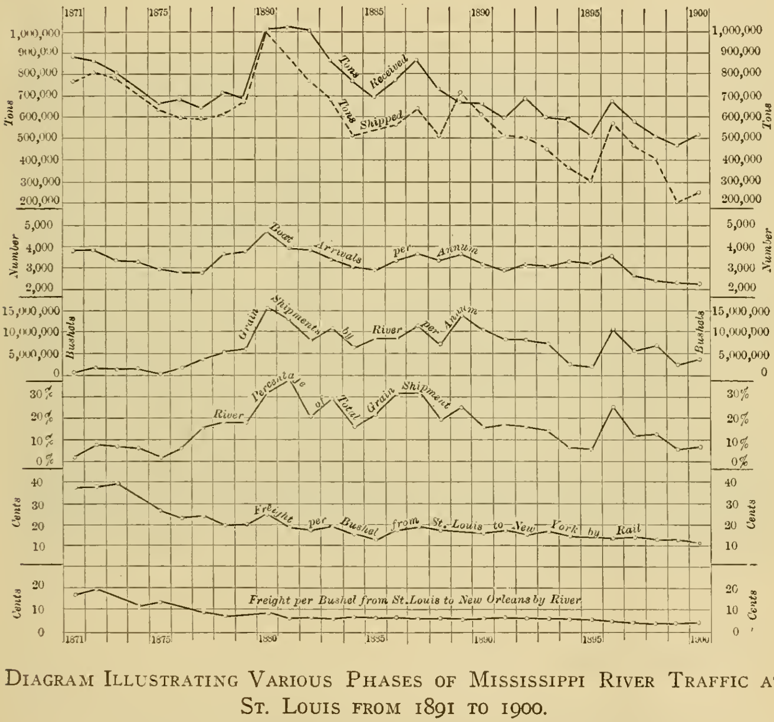


DIAGRAM ILLUSTRATING VARIOUS PHASES OF MISSISSIPPI RIVER TRAFFIC AT ST. LOUIS FROM 1891 TO 1900.

traffic, the decline has not been a gradual or systematic one. The fluctuations were great, even during the earlier years, when steamboat traffic was regarded as flourishing.

On the whole the decline in volume of river traffic at the port of St. Louis has not been as great as commonly believed, and the traffic is still a very important factor in the problem of cheap transportation, which becomes more and more important as margins of profit in trade and manufacture grow smaller. The inevitable result must be an increasing use of the river as a commercial highway as the improvement of the stream continues, and finally estab-

lishes the fact that shipments can safely be made and their delivery assured without any delays due to deficient depth of channel.

GRAIN TRADE.

The volume of the grain trade of St. Louis since 1865 has varied with the development of the unsettled territory west of the Mississippi and with the foreign demand.

The former has resulted in a very large increase in the annual production. The amount exported depends on both the surplus at home and the demand abroad, and these may cause wide variations from year to year in the volume of export business. The volume of business of 1900 by river and rail combined has been exceeded by only two preceding years,—viz, 1889 and 1890, the total shipments during the latter year being 65,155,187 bushels of grain.

The average annual shipments of grain by river, 1871 to 1875, inclusive, were 1,025,742 bushels, while for a corresponding period, 1896 to 1900, inclusive, the annual average has been 5,668,596 bushels, or more than five times as large as the period often alluded to as the flourishing days of river traffic. The volume of river grain traffic varies widely with different years. In 1880, just after completion of the jetties, it reached 15,762,664 bushels, and in 1889 it reached 14,158,046 bushels, while it was less than one-half the latter amount in 1884. During the years 1871 to 1875, inclusive, 4.5 per cent. of the total grain shipments from St. Louis were carried by river. During the years 1896 to 1900, 12.0 per cent. of the total grain shipments were carried by river, reaching a maximum for the period under consideration of 25.5 per cent. in 1896. The highest percentage of total shipments was made in 1881, when the river shipments reached 37.9 per cent. of the total grain shipments. Over 30 per cent. of the grain was shipped by river in the years 1880, 1886 and 1887.

FREIGHT RATES PER BUSHEL OF WHEAT.

A great reduction in rates of freight has taken place since 1865, both by rail and river; but the river has always taken the lead in these reductions. From 1865 to 1881, there was a steady decline in river rates. From 1881 to 1891, the rates were quite steady, and then followed a gradual decline to the year 1900. In 1865 the average published rate on wheat was 30.6 cents per bushel by river from St. Louis to New Orleans. The average rate for the year 1900 was 4¼ cents, a decline of over 26 cents per bushel.

In 1865 the average published rate on wheat, St. Louis to New York by rail, was 70.2 cents per bushel; in the year 1900 the aver-

age rate was 11.6 cents per bushel. The average rate by river for the five years 1865 to 1869, inclusive, was 24.8 cents per bushel, while for the five years 1896 to 1900 the average was 4.62 cents per bushel, including transfer to ships for export. This is equal to $1.54 per ton, and gives a ton-mile rate of 1.3 mills. The average rail rate, St. Louis to New York, during the same period has been 13.2 cents per bushel. This is $4.40 per ton, or about 4.4 mills per ton-mile. This is more than three times the river rate per ton-mile. The later years have been used in these comparisons as giving the railways the benefit of all the latest traffic improvements, and the rates quoted are presumably as low as consistent with the

SIDE-WHEEL PACKET.
Loaded to the guards with miscellaneous package freight.

actual cost of transportation, and probably below the profitable limit.

On the other hand, methods of river traffic have made little or no progress since the advent of the barge lines, either in economy or efficiency, while the railways have made great strides in both.

The tabulation also shows the average annual rates per bushel of wheat from St. Louis to Liverpool by the Mississippi River via New Orleans, and by rail via New York, for the years 1883 to 1900, inclusive. The rates for the earlier years were not readily obtainable. The eighteen years show an average of 6.85 cents per bushel in favor of the river route. Some years it ran as high as 9½ cents per bushel. Apply this to the output of grain in the territory tributary to the Mississippi River, and the aggregate is a sum

River Business, Port of St. Louis, Mo.

Year.	Total Boats Arrived.	Total Tons Freight Received.	Total Tons Freight Shipped.	Grand Total of Freight, Tons.	Total Grain Exports by Both Rail and River, Bushels.	Grain Exports by River, Bushels.	Percentage of River Traffic to Whole Grain Traffic.	Freight per Bushel of Wheat St. Louis to New Orleans, Cents.	Freight per Bushel of Wheat St. Louis to New York, Cents.	Freight per Bu. of Wheat St. Louis to Liverpool via River and New Orleans, Cents.	Freight per Bushel of Wheat St. Louis to Liverpool via New York, Cents.	Difference in favor of River Route, per Bushel, Cents.
1865	3,908				13,427,052			30.6	70.2			
1866	4,114				18,835,969			27.6	54.0			
1867	3,425				14,249,752			30.0	72.0			
1868	3,471				11,860,097			21.0	48.6			
1869	4,029				16,148,756			15.0	42.0			
1870	3,991				21,039,776	66,000	0.31	18.0	32.0			
1871	3,739	883,401	770,498	1,653,899	21,587,187	312,077	1.4	16.8	37.2			
1872	3,831	863,919	805,282	1,669,201	23,885,784	1,711,039	7.2	19.0	37.8			
1873	3,336	810,055	783,256	1,593,311	22,549,739	1,373,969	6.9	15.7	39.1			
1874	3,283	732,765	707,325	1,440,090	24,417,411	1,423,046	5 8	11.7	33.2			
1875	2,945	663,525	639,095	1,302,620	20,649,147	308 578	1.5	13.4	27.1			
1876	2,805	688,755	600,225	1,288,980	28,907,601	1,774,379	6.1	11.0	23.3			
1877	2,810	644,485	597,670	1,242,155	25,333,588	4,101,353	15.1	8.5	24.6			
1878	3,613	714,700	614,675	1,321,375	29,432,435	5,451,603	18.5	7.25	19.8			
1879	3,831	688,970	676,445	1,365,415	33,676,424	6,164,838	18.3	7.75	20.3			
1880	4,692	1,092,175	1,038,350	2,130,525	48,321,983	15,762,664	32.6	8.25	25.2			
1881	3,951	1,208,430	884,025	2,092,455	39,509,218	12,993,947	37.9	6.00	19.2			
1882	3,847	1,073,570	769,905	1,843,475	41,540,103	8,333,417	20.6	6.42	17.7			

River Business, Port of St. Louis, Mo.—(Continued).

Year.	Total Boats Arrived.	Total Tons Freight Received.	Total Tons Freight Shipped.	Grand Total of Freight, Tons.	Total Grain Exports by Both Rail and River, Bushels.	Grain Exports by River, Bushels.	Percentage of River Traffic to Whole Grain Traffic.	Freight per Bushel of Wheat St. Louis to New Orleans, Cents.	Freight per Bushel of Wheat St. Louis to New York, Cents.	Freight per Bu. of Wheat St. Louis to Liverpool via River and New Orleans, Cents.	Freight per Bushel of Wheat St. Louis to Liverpool via New York, Cents.	Difference in favor of River Route, per Bushel, Cents.
1883	3,425	860,540	677,340	1,537,880	37,632,949	11,059,508	29.4	5.50	19.8	19.61	27.00	7.39
1884	3,047	760,685	514,910	1,275,595	41,227,380	6,647,558	16.1	6.62	15.6	14.61	21.25	6.64
1885	2,908	696,925	534,175	1,231,100	38,833,580	8,667,919	22.3	6.40	13.3	15.11	20.50	5.39
1886	3,356	770,990	561,895	1,332,885	27,690,878	8,834,924	31.8	6.50	17.4	16.16	24.00	7.84
1887	3,633	866,045	637,060	1,503,105	36,003,822	11,556,799	32.1	6.00	19.2	15.00	24.50	9.50
1888	3,323	728,808	510,115	1,239,023	38,402,167	7,252,578	18.9	6.50	17.4	15.16	22.95	7.79
1889	3,669	671,685	712,700	1,384,385	56,232,700	14,158,046	25.2	5.95	16.8	17.33	24.97	7.64
1890	3,201	663,730	617,985	1,281,715	65,155,187	10,217,244	15.7	6.58	16.2	14.33	21.48	7.15
1891	2,900	592,140	512,930	1,105,070	51,350,319	8,468,546	16.5	6.87	17.4	15.75	23.55	7.80
1892	3,143	687,200	502,215	1,189,415	53,545,976	8,414,940	15.7	6.50	15.7	14.00	21.00	7.00
1893	3,040	599,405	436,900	1,036,305	51,487,600	7,079,598	13.8	6.55	17.1	14.71	21.72	7.01
1894	3,306	583,530	363,080	946,610	35,170,487	2,345,503	6.6	5.89	14.8	11.69	18.71	7.02
1895	3,133	508,830	303,355	812,185	29,339,368	1,690,417	5.7	5.95	14.1	12.12	18.33	6.21
1896	3,490	671,765	572,410	1,244,175	41,200,512	10,527,208	25.5	5.00	13.8	13.50	19.67	6.17
1897	2,619	576,670	469,365	1,046,035	46,987,028	5,475,342	11.6	4.88	14.2	12.89	20.33	7.44
1898	2,372	506,585	399,583	906,168	52,722,679	6,600,707	12.5	4.50	13.3	14.24	20.32	6.08
1899	2,250	466,610	203,205	669,815	41,028,533	2,233,235	5.4	4.50	13.2	12.33	17.88	5.55
1900	2,217	512,010	245,580	757,590	54,606,499	3,506,491	6.4	4.25	11.6	14.64	18.41	3.77

of enormous proportions, which should have been largely divided between the producers and consumers rather than have it absorbed in high transportation charges.

Combining the known volume of freight carried by river during the years 1896 to 1900 from St. Louis, coal from the Ohio and the local traffic of Memphis and Vicksburg gives an average of about 2,785,550 tons per annum. This is doubtless far below the total amount of the traffic on the lower Mississippi River. The total traffic of the Mississippi River system must be many times this amount, reaching so great a volume as to become a highly important factor in the transportation problems of the country, and one which is of vital interest not only to the people of the Mississippi Valley, but to the entire country. The census report gives the volume of traffic for 1890 as 29,000,000 tons.

The main stem of this system has ample capacity for an enormous increase in the volume of traffic by making such practicable improvements as will insure a navigable depth at all stages that will fully satisfy the requirements of commerce.

Good use should be made of the river during our World's Fair by bringing exhibits from foreign countries to the port of New Orleans, and thence by river to St. Louis. This would result in considerable economy to shippers. As both delivery and return of shipments would be made at times when navigation is invariably good, there need be very little hesitation in encouraging transportation by this route.

While this great river has few if any parallels, the problems are most intricate and interesting; and their solution will doubtless keep the engineer busy for years to come. Little by little, step by step, the skill of the engineer will find means of overcoming the difficulties, until finally the great forces of nature pent up in the giant stream will yield to his bidding and become subservient to the requirements of man. Then will it indeed "flow unvexed to the sea," bearing in safety the products of the Mississippi Valley from the Great Lakes to the Gulf of Mexico, whence they will be distributed to the uttermost parts of the earth.

The very heart of our country will then be put in touch with the commerce of South America and, through the Isthmian Canal, with the great markets of the Orient.

THE ABOLITION OF GRADE CROSSINGS ON THE PROVIDENCE DIVISION OF THE NEW YORK, NEW HAVEN AND HARTFORD RAILROAD, BETWEEN BOSTON AND DEDHAM.

By Arthur S. Tuttle, Principal Assistant Engineer on the Work.

[Read before the Boston Society of Civil Engineers, September 18, 1901.*]

Before the abolition of its grade crossings between Boston and Dedham, the Providence division of the New York, New Haven and Hartford Railroad had its terminal at Park Square. Its main line from Park Square to Washington street, near Forest Hills, a distance of about 4½ miles, was crossed at grade by eleven highways. Its West Roxbury branch, running from Forest Hills to Dedham, about 4½ miles, was crossed at grade by four highways; and its Dedham branch, running from Readville to Dedham, about 2¼ miles, was crossed at grade by four highways. One of the latter, Milton street, at Readville, also crossed at grade the then New England Railroad, now the Midland division of the New York, New Haven and Hartford Railroad. There were no grade crossings on the main line between Washington street, near Forest Hills, and Readville. (See Fig. 1.)

A heavy train service was maintained on this division, about two hundred regular trains being handled daily at Park Square station.

The numbers of persons and teams using the eleven main line crossings in twenty-four hours, as determined by actual count, were 85,107 persons and 12,452 teams, amounting in one year to over 31,000,000 persons and over 4,500,000 teams. To protect this highway travel during the passage of the two hundred daily trains, the crossing gates were closed, during the same twenty-four hours, a total of forty-one hours and forty-seven minutes, which was nearly equivalent to the permanent closing of two crossings, provided the other nine were left open the whole time. Under these conditions, the maintenance of these crossings at grade constituted not only a grave menace to public safety, but also a great and annoying interruption to public convenience.

As far back as 1884 surveys were made for carrying all of these crossings over the tracks, the tracks to remain at the old grade, but the estimated cost of $3,600,000 seemed so excessive that at that time nothing further was done.

*Manuscript received October 21, 1901.—Secretary, Ass'n of Eng. Socs.

In a report concerning the gradual abolition of the grade crossings in the State of Massachusetts, made to the legislature in 1889, by Augustus W. Locke, Wm. O. Webber and George A. Kimball, engineers, it was recommended that these main line crossings should be abolished by raising the tracks about 13 feet from Roxbury to Forest Hills, with a grade of 29 feet per mile north of Roxbury and one of about 15 feet per mile south of Forest Hills, connecting with the old grade; and by depressing the streets amounts varying from 1 to 5½ feet; the total cost to be $1,350,000.

In 1890 the Old Colony Railroad Company, which then controlled the railroad, acting under the grade crossing act of 1890, petitioned the Superior Court to appoint three commissioners to prescribe the manner in which the Tremont street grade crossing should be abolished. Fig. 2 shows this crossing before the change. In 1892 a special legislative act was passed enlarging the powers of this commission to include all the main line crossings in the city of Boston; the Old Colony Railroad Company to do all the work and to bear 55 per cent. of the cost; the Commonwealth of Massachusetts to bear 31½ per cent. of the cost, and the city of Boston 13½ per cent. The commissioners appointed were S. N. Aldrich, E. B. Bishop and H. C. Southworth. Necessary hearings were held and plans considered, and June 23, 1894, their final report was filed, confirmed and made a decree of the court.

The requirements of the decree were, in outline, as follows (see Fig. 3): The main line of the railroad was to be raised, beginning near Massachusetts avenue and rising to Roxbury station, where it should be about 20 feet above the old tracks; thence continuing about 20 feet above the old tracks to Washington street, thence descending for about 3000 feet to the old grade. The West Roxbury branch was to be raised about 20 feet at the main line and descend for about 1700 feet to the old grade.

Heavy retaining walls, ranging from 6 to 30 feet high, were to be built on either side of the railroad where the adjoining land was closely built upon, as shown by the heavy lines on the plan, and at other places land was to be taken and the earth embankment was to take its natural slope. A little over 3 miles in length of wall was required.

Four tracks on the main line and three on the West Roxbury branch were to be laid with 100-pound steel rails where the grades were changed. A new freight yard was to be built on the westerly side of the main line, between Center street and Mozart street. A siding was to be laid on the easterly side of the main tracks from Jamaica Plain to the Parkway at Forest Hills.

The old station on the easterly side of the tracks at Roxbury and the one on the westerly side at Boylston street were to be raised to the new grade of the tracks and stone basements built underneath, and new stations were to be built on the opposite sides. At Heath street, Jamaica Plain and Forest Hills new stations were to be constructed, one on each side of the tracks. A driveway 40 feet wide was to be carried under the railroad at the south end of Roxbury stations, and at the other stations subways 10 feet wide and 8 feet high were to connect the two station buildings.

FIG. 2. TREMONT STREET GRADE CROSSING.

Stony Brook, near Boylston street station, was to be changed, and a new channel constructed for it about 2600 feet long, 2300 feet of it being depressed in grade about 11 feet and carried in a brick conduit, and about 300 feet of it being carried at the old grade in an open walled channel. Near Forest Hills, a new channel was to be constructed for the brook, 10 feet wide at the bottom, with earth side slopes and with a double brick conduit connecting the new channel with the old double-arched stone culvert under Walk Hill street.

The brick arch over Stony Brook on the main line between Forest Hills and Mt. Hope and the Bussey farm arch on the West

Roxbury branch were each to be extended to carry one additional track.

A subway 10 feet wide and 8 feet high was to be built under the main tracks about 700 feet north of Ruggles street for convenient access to the railroad company's repair shops.

Under the tracks as raised, the highways were to be carried as follows: Ruggles street was to be depressed at the railroad 4½ feet, Prentiss street 0.7 of a foot, Tremont street 1 foot and Boylston street 1½ feet. Center sreet, which at that time was carried on a bridge over the railroad, was to be depressed 17½ feet, and changed in grade for a length of nearly 1000 feet. West of Lamartine street, it was to be widened from 50 to 60 feet; between Lamartine street and Amory street it was to be 70 feet wide, and to cross the railroad more nearly at right angles than before, and east of Amory street it was to be from 80 to 140 feet wide. Walk Hill street, where it crossed the West Roxbury branch, was to be discontinued, and laid out 50 feet wide across the main line to Washington street. The remaining streets were to be unchanged, both in line and in grade. The railroad was to be carried over Morton street and the Parkway by stone arches, over Tremont street and Walk Hill street by steel arches and over the other streets by plate girder bridges. Two additional plate girder bridges were to be built for the future laying out of Mozart street and Williams street. The required headrooms under the bridges varied from 13 to 16½ feet.

To carry out the provisions of the decree, it was necessary, first, to construct the new channels for Stony Brook, and October 25, 1894, a contract for this work was made by the New York, New Haven and Hartford Railroad Company, lessee of the Old Colony Railroad, with the Metropolitan Construction Company, and work was at once started. At Boylston street the excavation above the ground water level and above ledge was taken out by men shoveling directly into carts. The deeper excavation at the southerly end, where the material was hard pan, was handled with a Carson Trainor trench machine; the rock near the middle was handled with derricks, and at the north end, where the material was chiefly quicksand, a cableway about 700 feet long was used. As the old brook channel was only about 7 feet from the nearest line of the trench, the bottom of which was 12 feet below the bed of the brook, and as the main tracks of the railroad, on which trains were frequently passing, were close to the other side of the brook, very great care was required in placing and maintaining the sheet piling and bracing. The quicksand excavation was made in sections of

about 20 feet in length, sheet piling being driven across the trench, as well as on the sides, and thoroughly braced, the sand taken out and the invert foundation put in as rapidly as possible; then the next section was excavated to sub-grade before the sheeting between the two sections was removed. The trench was kept clear of water by an underdrain, which carried the water to a sump at the north end, whence it was raised by a steam pump and discharged into the brook below the work. The covered conduit (Fig. 4) as built consisted of a concrete invert foundation 6 inches thick, laid on from 6 to 12 inches of gravel, refilling where quicksand was encountered, but laid directly upon the natural earth where it was

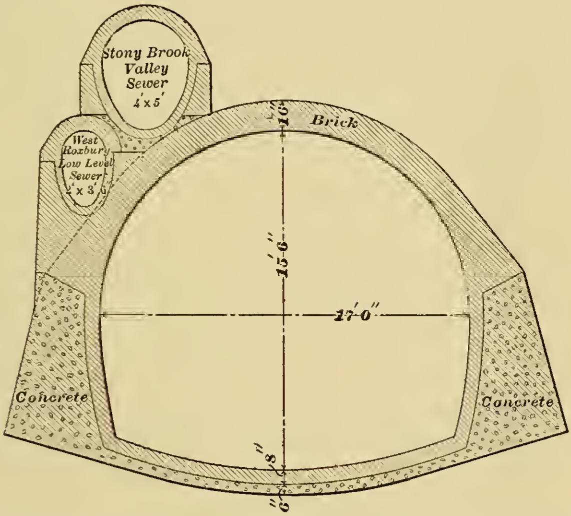


Fig. 4. Cross-section of Stony Brook Conduit near Boylston Street Station.

firm and compact. Concrete sidewalls were carried a little above the springing line of the arch. The invert foundation and sidewalls were plastered with cement mortar and lined with 8 inches of hard-burned brick laid in cement mortar. Where the conduit was built in rock, only enough concrete was put into the foundations and sidewalls to fill the inequalities in the rock left in blasting and to bring the inner faces to the proper lines for the brick lining and arch. The arch was of hard-burned brick laid in cement mortar, 16 inches thick at the crown, and the extrados was plastered with cement mortar. The inside dimensions of the conduit were 17 feet wide and 15½ feet high, large enough to allow of the passage of an ordinary railroad train. Upon the easterly haunch of the conduit, there was constructed the West Roxbury low-level

sewer, 2 x 3 feet 6 inches in size. Near Boylston street, there was also built upon this easterly haunch, and above the West Roxbury low-level sewer, about 560 feet of a 4 x 5-foot brick sewer to replace an elbow of the Stony Brook Valley sewer that was cut off by the new conduit, the sewerage being carried temporarily in a wooden flume fastened to the easterly side wall of the old brook channel. Two brick sewers and one pipe sewer were carried over, and overflows constructed into, the new conduit. The northerly end of the conduit was finished with a granite arch facing and squandrel wall, with sidewalls connecting with the old sidewalls, and a Portland cement concrete incline sloping from the low grade of the conduit up to the bed of the old brook. The southerly end of the conduit was finished with a similar arch facing and spandrel wall. The brick invert and sidewall lining, with heavy sidewalls built up to the surface of the ground, were carried about 20 feet south from the arch, and a dam wall built across and up to the level of the old bed of the brook. Southerly from this dam wall an open channel was constructed, with a concrete invert and granite sidewalls.

Connecting the upper end of this open channel, there was built a sand catcher, or settling basin, to stop and retain sand and other sediment brought down by the brook, and so constructed that sections of it could alternately be drained and cleaned while other sections carried the stream. An iron grating to catch driftwood, etc., and a footbridge over the basin were also placed here.

After the conduit at the northerly end had been completed the length of the cableway, the cableway was shifted to the south, a wooden bulkhead placed in the south end of the completed portion and the brook turned into the conduit through an opening left in the arch just below the bulkhead, and the old channel, where discontinued, used for a dump, an 18-inch drain pipe first being laid in the old channel.

After the completion of the whole channel, and at a time of low water in the brook, the stream was turned through this 18-inch pipe, the water in the conduit pumped out, the bulkhead removed, the hole in the arch repaired and the brook then turned through the completed channel.

The excavation for the new channel at Forest Hills was slight and simple. The covered connection with the culvert under Walk Hill street consisted mainly of a double conduit, with rubble sidewalls and a brick center pier, each 4 feet high, and semicircular arches of 8-foot span, 12 inches thick at the crown, the whole resting upon five longitudinal 6 x 6-inch spruce sills covered with 3-

inch plank. The total length of the conduit was 170 feet, and a little below the middle point in this length there was constructed a distributing chamber 17 feet 4 inches wide and 15 feet long, into which flowed the Bussey Park branch of Stony Brook, which was carried under the West Roxbury branch tracks in an 8-foot diameter circular brick conduit. The upper end of the new double conduit was finished with a stone arch facing and spandrel wall and necessary wing walls. The old double-arched stone culvert under Walk Hill street and the main line tracks was strengthened to sustain the additional 20 feet of filling and the retaining wall on the easterly line of the railroad by covering the arches with 18 inches of concrete.

The total cost of this Stony Brook work was about $200,000. While this Stony Brook work was going on, plans for the main work were being prepared, buildings in the way were being torn down or moved out of the way and temporary tracks were being laid. Over 120 buildings of all kinds, from a shed to a large three-story brick factory, were either torn down or moved away. One large three-story brick machine shop, with long lines of shafting, was moved lengthwise about 300 feet and then back 50 feet, the machinery inside being kept constantly at work.

The work was divided into two sections, all north of and including Center street being on Section 1, and all south of Center street, Section 2. (See Fig. 3.)

The engineer corps, as organized to look out for the work, consisted of an assistant engineer of construction in personal control of the whole work, reporting to the chief engineer in New Haven, Conn.; a principal assistant engineer, two second assistant engineers, each with a party of one transitman and two rodmen, one party giving lines and grades on Section 1 and the other on Section 2; one cement tester, who tested on an average samples from one barrel in ten of those ordered for the work, and four inspectors; a total of sixteen men.

June 25, 1895, contracts were made with H. H. Brown for the work on Section 1, and with J. J. O'Brien for the work on Section 2.

At that time the railroad between Park Square and Readville was operated with a left hand running double track and a third track west of the double track, used by northbound trains in the early mornings and by southbound trains in the late afternoons, for the accommodation of the heavy suburban traffic. It was impracticable to maintain these three tracks for regular service and construct any part of the new work, especially on Section 1, which in

one place was only 53 feet wide, and regular traffic was therefore limited on Section 1 to the old double track, which was connected at Center street with a temporary double track on Section 2 laid east of the old double track on land taken or purchased. No track connection was permitted with this double track between Forest Hills and Chickering.

On Sunday, September 22, 1895, the regular traffic was transferred to these temporary tracks, and the interlocking tower at Forest Hills was disconnected from the old West Roxbury branch junction switches and signals and connected with the temporary junction switches and signals, there being only the one day when the tracks were not controlled from the tower.

This same day all double track of the Old Colony system of the New York, New Haven and Hartford Railroad was changed from left hand to right hand running. While this did not require many track changes on the grade crossing work, it did necessitate many precautions being taken to protect the men, who had become accustomed to left hand running and who, under the stress of the construction work going on, were liable to forget that trains were running right-handed. The old third track was used as a construction track, for the handling of stone and other construction material. A storage yard, for receiving construction freight, was constructed at Forest Hills.

The following printed rules were issued:

OFFICE OF ASST. ENGINEER OF CONSTRUCTION, N. Y., N. H. AND H. R. R., OLD COLONY SYSTEM, JAMAICA PLAINS, MASS.

RULES FOR THE GOVERNMENT OF ENGINEERS AND INSPECTORS.

Main tracks must be kept clear for the safe passage of trains at all times.

Contractors are not allowed to cross main tracks with materials, except in the usual way at street crossings that are protected by gates.

In case of an accident where one or more of the main tracks is obstructed the first thing to do is to send flags out in both directions, at the same time notifying, by telegraph, this office and also the office of the superintendent in Park Square station, Boston, of the nature of the accident, what tracks are blocked, and how long it will take to clear them. Take all the men in call on the work to clear the tracks.

Contractors must provide and keep along the work sets of emergency tools, such as axes, saws, tackle, etc., where they can be gotten at in case of accident.

Telegraph wires must not be interferred with. In case they are in the way, notify this office that a lineman is needed to look after them, and they are not to be touched without his consent.

All derricks that are set up so that the boom can reach over a main track must have boom fastened with guy rope, or posts must be set in the ground so as to prevent it swinging out over the main track at any time.

Foremen must inspect all guys every morning at each derrick.

In case it is necessary to take a guy line across tracks permission must first be asked of this office for necessary flagman (and lineman for wires if required), and the crossing of tracks with line must be done under direction of the section boss and under flags put out in both directions to protect trains.

Contractors' men are not allowed to fasten guys or the like to the tracks or to the false work carrying tracks.

Contractors must not unload from cars on construction track while regular trans are passing or aproaching on main tracks.

Contractors will be allowed to work near the construction track, provided flags are put out in both directions at least 500 feet away on this track.

At no time must the construction track be blocked in such a manner that it cannot be at once freed. Trains must be expected on this track, in either direction, at any time.

All guys, where crossing tracks, must be at least 22 feet in the clear above the top of rail.

Contractors must have all excavations that are made near public travel, and all obstructions in public highways, properly protected by fences, and well lighted at night.

During heavy rainstorms, engineers and inspectors must be upon their work to guard against all possible accidents.

No excuse will be taken for disobedience of orders or carelessness, and inspectors will report any violation of rules or any carelessness on the part of contractors' men. Per order,

C. M. Ingersoll, Jr.,
Asst. Engr. of Const.

Early in July, 1895, work was started by the contractors. On Section 1 derricks were erected every two or three hundred feet between the construction track and the westerly retaining walls from Old Heath street to Prentiss street, a distance of about three-quarters of a mile. North of Ruggles street, for about a third of a mile, they were placed on the westerly side of the wall.

On Section 2 the temporary main tracks were laid far enough to the east so that the retaining walls and westerly portions of the abutments could be built at the same time, and derricks were erected at the streets as well as along by the walls.

The lowering of the street grade at Ruggles street was such as to require the reconstruction of a portion of Stony Brook channel which ran through Ruggles street and Rogers avenue.

A double brick conduit was built, with a flatter section and at a lower grade than the old culvert, making a slight depression or siphon in the line of grade. The alignment was also changed to avoid the middle pier of the railroad bridge. Ruggles street was closed to highway travel during this work, the travel using Prentiss street, and the tracks were supported by temporary stringers and blocking.

At Center street the highway was closed to teams, but a foot-bridge was maintained over the tracks north of the old highway bridge while the southerly portion of the street was lowered to the new grade. A new sewer, new water pipes and gas pipes were laid, and the street railway company laid as much of their permanent track as could be put in. Walk Hill street was closed from the beginning to the end of the work. The other streets were kept open, except Tremont street, which was closed for a short time, as will be mentioned later.

Very large quantities of stone and cement were required, and in order to expedite the work it was essential that plenty of stone should be on hand to select from, and that it should be placed promptly.

A daily stone train was run between the Quincy quarries and the Forest Hills storage yard, constructed to receive this freight, as before mentioned, quite a surplus being kept in the yard. Stone came also from Fitchburg, Pascoag and even from Maine. At times there were as many as 250 cars of stone on hand. Each afternoon the contractors looked over the stone and made lists of the cars wanted placed the next day, stating at which derricks they were needed. The assistant roadmaster, in charge of the construction train service, rearranged these lists in the order in which the cars would be required placed on the construction track, and gave the revised list to the train crew, who made up the train in the required order and as early as possible the following morning backed the whole train to the north end of the work and on the way back dropped the designated cars at the appropriate derricks. Late in the afternoon this same crew took away the empty flat cars and placed at the derricks empty gondola cars, which were loaded during the night with material taken from the foundations by the excavation gangs working by electric light. Early in the morning, the loaded gondola cars were taken away, leaving the track clear for the morning stone train.

The inspectors submitted daily reports, on printed cards, of work done at each derrick, stating kind of work, location, whether done by company or contractor, number of men of each class of labor, time of starting and stopping, approximate amount of work done and what was required if delay was liable to ensue because of lack of men or materials.

After the westerly retaining wall on Section 1 was completed the construction track was taken up and the abutments for two tracks constructed, the stone being unloaded from the main tracks at night and piled up near the work, to be laid the following day.

Masonry was laid both summer and winter, brine being used in the mortar in very cold weather.

The temporary trestles were also erected as soon as the construction track was taken up. There was constructed a single track trestle north of Ruggles street, a double track trestle from Prentiss street to Center street, a double track trestle over the track leading into the Forest Hills freight yard and a double track trestle from Morton street to Washington street, passing over the West Roxbury branch temporary tracks.

FIG. 5. RETAINING WALL AT JAMAICA PLAIN AND GREEN STREET BRIDGE.

Where no trestles were built, the tracks were laid on the permanent embankments. The trestles were built all of hard pine, with 12 x 12-inch sills, posts and caps, thoroughly braced with 4 x 8-inch bracing. Bents were placed 12 feet apart on centers, with 4 x 8-inch longitudinal bracing in two of every three bays. Two 8 x 16-inch stringers, each 24 feet long and breaking joints at the bents, were placed under each rail. Ties were 6 x 8 inches, and guard timbers were of the same size and placed outside of each rail. On curves, the elevation of the outer rail was obtained by tapered shim blocks placed one on each tie.

The retaining walls and abutments were built of cut stone face masonry and rubble backing, laid solid in cement mortar. The wall under the dressed coping, which was 3 feet wide and 15 inches

deep, was 3 feet thick, plumb on the face, and battered down on the back 4 inches to a foot until the thickness equaled one-half the height, where the batter was increased to 6 inches to a foot. The two upper courses of the coping were chamfered, and in the vicinity of stations a neat and strong iron fence was set in the top of the coping. Fig. 5 shows the wall and iron fence and the bridge at Green street.

Tremont street crossed the railroad on quite a skew, and the abutments were built in a succession of jogs to support the ribs of the steel arch, which lapped by each other. Great care was required in the setting of the skew back stones.

South of Tremont street, Stony Brook flowed under the railroad and under a part of the westerly retaining wall in a brick

Fig. 7. Completed Parkway and Morton Street Arch Viaduct.

conduit of the same size as that hereinbefore described as built near Boylston street. To strengthen this conduit so as to safely carry the weight of the retaining wall, applied on one side only, and also the weight of the additional 20 feet of filling, the conduit arch was uncovered, and the space between the sides of the old rock trench in which it was constructed was filled level with concrete to a height of 18 inches above the crown of the old arch.

Between Forest Hills and Mt. Hope, the Stony Brook brick arch, carrying three tracks, was lengthened out to take the fourth track.

The Bussey farm arch was lengthened out to carry the new third track on the West Roxbury branch.

The five-stone arch viaduct at Forest Hills, four arches being over the Parkway and one over Morton street, is particularly

worthy of notice. Fig. 6 shows a right-angle section of the arches. The two end arches, the south one being for Morton street, had spans of 41 feet at right angles to their axes, the middle one a span of 45 feet and the two intermediate ones spans of 23 feet. The abutments were 17 feet thick at the bottom and 12 feet thick

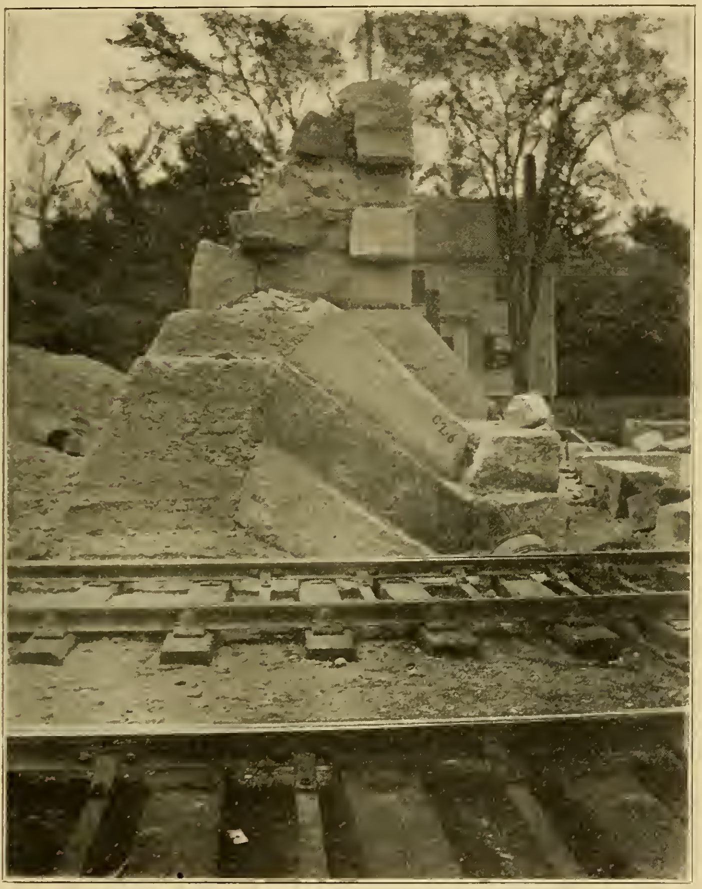


FIG. 8. SECTION OF WALK HILL STREET STEEL ARCH ABUTMENT, FOREST HILLS.

at the spring. The piers were 16 feet thick at the bottom and 9 feet 4 inches thick at the spring. The angle of the faces with the axes was 63° 03′.

The abutments, piers and spandrel walls were built in courses, the top course just below the parpet being a variable course 1 foot 8 inches high over the middle arch and 4 inches high at the backs of the abutments. The parapet was quite ornamental, rising to a height

of about 6 feet above the level of the railroad tracks. The ends of the abutments and piers were finished in the form of buttresses, which were carried up to the top of the parapet. The ring stones were 2 feet 6 inches deep, except on the ends, where they were made deeper for architectural effect. The soffits were fine-pointed, the parapet either fine-pointed or fine-hammered and all other stone left with rock face. The upper surfaces of the arches were waterproofed with a layer of Portland cement mortar covered with ten layers of tarred paper, each thoroughly mopped with hot asphalt. The valleys between the arches were drained by 4-inch iron pipes extending down through the centers of the piers to about 4 feet underground, where they turned and connected with drain pipes, emptying into low ground northeast of the arches. A sufficient length of the westerly ends of these arches was constructed to carry the two westerly high tracks. Fig. 7 shows the completed structure.

The abutments for the Walk Hill street steel arch were built with inclined stones and Portland cement backing. Fig. 8 gives a comprehensive section of this masonry.

The station subways were built with abutments of rubble masonry, faced with white enameled brick, with a 2-inch air space between. Fig. 9 shows the subway at Forest Hills. The brick arches consisted of soffit courses of enameled brick and four other courses of hard-burned brick. The ends of the arches and abutments were finished with stone voussoirs and courses. At the stations the retaining walls were built to allow for wide platforms at the level of the tracks, with necessary stone steps giving convenient access to the streets.

The westerly stations were erected as soon as the retaining walls past their sites had been constructed. The basements were constructed with stone walls similar in color to the stone in the retaining walls, and lined inside with buff-colored brick. Stairs to the track floors and baggage rooms and the necessary heating apparatus were constructed in them. The upper stories were constructed with light-colored brick walls, sheathed up to the window sills inside in oak and lined with buff brick above the sheathing. The inside arrangements were convenient and commodious, with ticket offices and waiting, baggage and toilet rooms; suitable cover sheds were constructed over the track platforms.

At Forest Hills an approach was constructed, on the westerly side of the tracks, from the corner of Morton and Walk Hill streets up to the track platforms. At the other stations station grounds were constructed at the level of the adjoining streets.

While all this work was being done by the contractors, the roadmaster and his assistant were bringing in gravel filling, sometimes at the rate of from 60,000 to 70,000 cubic yards a month. At the beginning of the work the gravel was loaded at Readville pit by steam shovel and hauled in trains of dump cars, but after about 200,000 cubic yards had been taken from Readville pit the steam shovel was moved to Sharon pit, a large pit on the main line, about 13 miles from Forest Hills. Because of the long haul on the main line, the use of dump cars was discontinued and gondola cars substituted. These were large cars, holding 25 cubic yards each, equipped with air brakes and constructed with hinged sides, which

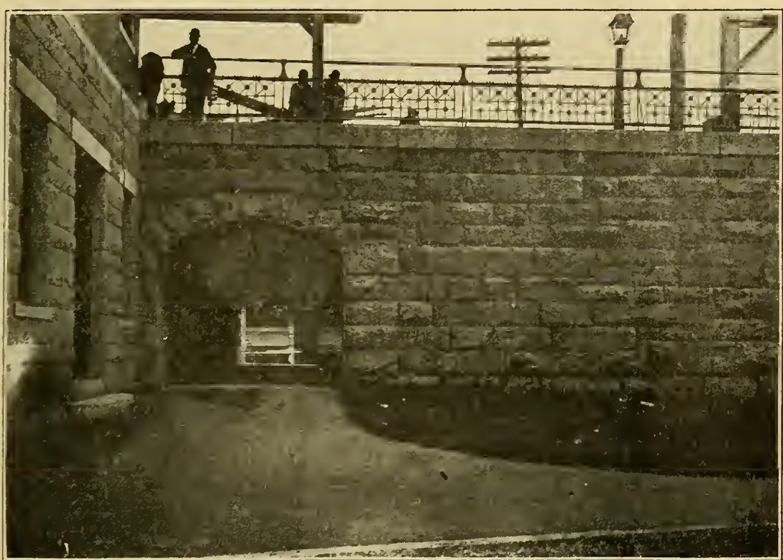


Fig. 9. Forest Hills Subway.

when raised allowed about one-third of the load to fall out, the other two-thirds having to be shoveled out; 20 cars made up a train.

No filling could be deposited on Section 1 until after the wall was built, but on Section 2 there were long stretches where no walls were required and where the fill could be made at once. South of Washington street, considerable filling was put under the main tracks, the regular trains continuing to use the tracks, the tracks being raised over 8 feet in this way. As fast as the filling was brought up to the tops of the abutments on Section 2 the filling track was carried across the streets on temporary trestles and connected with the construction track on Section 1. The low construction track on Section 2 was then taken up and the embankment

widened out, and when regular traffic was transferred to the two westerly high tracks a filling track had been laid on the embankment east of the main tracks for the whole length of Section 2 north of Forest Hills. Tracks were laid on the trestles as soon as completed, and as much filling placed as could be put in without obstructing the low main tracks.

As fast as the bridges were received they were erected in place by the bridge contractor's men.

Most of the girder bridges were half-through bridges, and when in place the tops of the girders came but very little, if any, above the tops of the rails. Where station platforms were carried

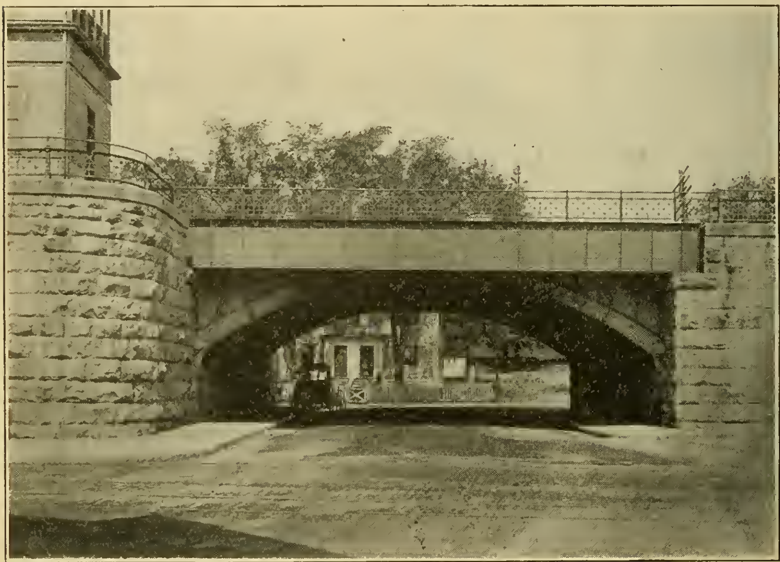


FIG. 10. WALK HILL STREET STEEL ARCH, FOREST HILLS.

over the bridges, fence girders were placed on the outside of the platforms. All of the steel bridges had tight ballast floors. The entire bridge was painted with two coats of red lead; the upper floor surface was then swabbed with hot asphalt; screened gravel was placed around the drainage holes in both ends of the troughs and the rest of the troughs filled with mastic ballast, consisting of screened gravel and enough asphalt to make the stones stick together, but not to fill the voids between the stones. Small screened gravel ballast was then put on the floor and the ties bedded in it. Under the drainage holes were suspended copper gutters, leading either to pipes passing through the parapets into the drains to the sewers, or to down spouts emptying into the street gutter. The

bridges were finally painted one coat of the standard color for track bridges.

The Walk Hill street steel arch (Fig. 10) is a two-hinged arch built square. The Tremont street arch (Fig. 11) is a three-hinged arch on quite a skew. Fig. 11 shows also the Roxbury driveway plate girder bridge.

The two westerly tracks were laid with 100-pound steel rails, and the Forest Hills junction was controlled from a temporary interlocking tower.

Sunday, August 23, 1896, thirteen and one-half months after the beginning of the main work, all regular trains were transferred

FIG. 11. TREMONT STREET STEEL ARCH AND DRIVEWAY BRIDGE, ROXBURY.

to the two new high tracks. As soon as this transfer was made one of the old low main tracks was taken up and the other used as the new construction track. Derricks were erected and work at once begun on the easterly walls.

South of Tremont street, Stony Brook ran close to the railroad for a distance of about 600 feet, its westerly channel wall, about 10 feet high, sustaining the easterly side of the railroad. This wall was taken down and the new retaining wall started at the bed of the brook.

Center street was graded to its full width, the street car tracks laid and the surface of the street finished.

Lamartine street freight yard was completed and opened to the public.

After the retaining wall on Section 1 was completed, the construction track was taken up and the street abutments constructed, the stone being unloaded from the main tracks at night. On Section 2 the construction track was east of the retaining wall, and work on both the walls and abutments could go on at the same time.

At Roxbury the old station was raised and a stone basement constructed underneath. The other easterly stations were built similar to the ones on the westerly side, and station grounds graded and surfaced.

The Forest Hills freight yard was raised to connect with the main tracks. The filling was widened out from the main tracks, the low tracks being used for storage until the filling reached them, when they were taken up and relaid on the new fill. When the last low track was taken up, the track leading into the yard was also taken up and the gap under the main tracks filled in with gravel.

The filling on Section 2 was dumped from the filling track at the high grade in the day time. The filling on Section 1 was done largely from the main tracks at night. The greater part of this night filling was done in winter, and the cold was so great that the Italians who had been doing most of the grading work could not endure it, and a gang of Canadians was secured to finish this work.

South of Tremont street, filling was put in at night, until a siding could be laid from the main track running onto the new fill, down a steep grade to the old construction track and along to New Heath street. After this had been done gravel trains were backed onto this track and the filling then put in by day. The laying of the permanent easterly tracks folowed closely the completion of the embankments.

The two westerly high tracks were carried on trestle over Tremont street and Roxbury driveway, the bridges not having been received at the time trains were transferred to these tracks. After the bridge masonry had been completed and the bridge material received, the bridge for the westerly tracks at Roxbury driveway was erected in the place for the easterly tracks and the ballast and ties put on, and one Sunday night, after the last train had passed, the two westerly tracks over the driveway were taken up, the trestle removed, the new bridge slid over into its proper position and the tracks connected up again before the first morning train was due. The bridge for the easterly tracks was then erected and the roadway underneath surfaced. Tremont street travel was then

diverted through the driveway and the easterly half of the Tremont street arch erected.

May 2, 1897, the regular traffic was transferred to the two easterly high tracks and the westerly half of Tremont street arch was erected. At the same time the two westerly tracks on the trestles were taken up, the trestle ties, stringers, guard timbers and caps taken out and removed to the supply yards, and the tracks relaid, ballasted and surfaced.

June 21, 1897, almost exactly two years after the main work was begun, the four tracks were put into permanent service and the abolition of the grade crossings on the main line in the city of Boston had been accomplished.

The following quantities of masonry and other work were constructed: 123,000 cubic yards stone masonry, 21,000 cubic yards concrete masonry, nearly 8000 cubic yards of brick masonry, eight new brick and stone stations and two old stations raised and enlarged, nearly a mile of temporary double-track trestle and a half mile of single-track trestle, 13 four-track and two five-track steel bridges, about 19 miles of main track, four miles of freight tracks and about eight miles of temporary or filling tracks, and 1,200,000 cubic yards of earth embankment. About 31 acres of land were taken or purchased in connection with the work. The total cost of the work was $4,041,514.

Only one accident happened to a regular train during the whole work, and that was a very slight one, a pane of glass being broken in one of the local trains and one passenger cut slightly by the flying glass.

The plans accompanying the commissioners' reports were prepared under the direction of Mr. S. L. Minot and Mr. J. W. Rollins, Jr., but the execution of the work, from the beginning nearly to its close, was under the personal supervision and charge of Mr. C. M. Ingersoll, Jr., assistant engineer of construction. January 1, 1897, when the work was nearing completion, Mr. J. W. Rollins, Jr., took charge and completed it, Mr. Ingersoll leaving to assume the duties of assistant to the president of the railroad and later to become chief engineer, which position he now holds. All the filling and train work was done under the direction of the roadmaster, Mr. R. P. Collins, and his assistant, Mr. Hugh Steele.

FOURTH TRACK CONSTRUCTION, MT. HOPE TO READVILLE.

During the progress of the abolition of these main line crossings, an additional track was laid from Mt. Hope to Readville, thereby making the four-track service continuous from Boston to

Readville. A new station was built at Mt. Hope; the stations at Clarenden Hills, Hazelwood and Hyde Park were moved back and new station platforms constructed; the Stony Branch culvert, south of Clarenden Hills, extended to carry the fourth track, and a new bridge erected at Canterbury street spanning the four tracks.

In 1896 acts of the legislature were passed providing for the abolition of all grade crossings, both public and private, on the West Roxbury and Dedham branches, and of the grade crossings of Milton street and the New England Railroad at Readville; also providing for the construction of a new highway over the Providence division between Hyde Park and Readville stations; the crossings to be abolished and the new street constructed in the manner prescribed by commissioners to be appointed by the Superior Court. S. N. Aldrich, E. B. Bishop and H. C. Southworth, the same commissioners who prescribed the manner of abolishing the main line crossings in Boston, were appointed. Their report covering the crossings on the West Roxbury branch was confirmed by the court April 24, 1897, and their report covering the crossings on the Dedham branch and at Readville was confirmed May 7, 1897.

Before the work was begun the New England Railroad was leased to the New York, New Haven and Hartford Railroad Company, becoming the Midland division of the latter road.

December 27, 1897, contracts were made with Dwight & Daly for the work on the Dedham and West Roxbury branches, except the Milton street crossing, and with J. J. O'Brien & Co. for the work at Readville, and work was at once started.

WORK ON THE WEST ROXBURY BRANCH.

The three highway grade crossings abolished on the West Roxbury branch were South street at Roslindale, La Grange street at West Roxbury and Spring street at Spring street station. Several private crossings were also abolished.

South street was discontinued where it crossed the railroad and a new street, 60 feet wide, laid out from Brandon street to a point on South street a little south of South Walter street, crossing under the railroad tracks about 430 feet south of the old South street crossing. The railroad was raised at the new street 5 feet and carried over it by a plate girder bridge supported upon abutments and steel columns at the curb lines of the sidewalks. North from

the bridge the railroad ran on a descending grade of 1 per cent. for about 4000 feet, and south from the bridge on an ascending grade of 0.4 per cent. At the old South street crossing a subway for foot travel was constructed. The railroad was carried over this subway by a steel solid-trough flooring, resting upon abutments of rubble masonry faced with white enameled brick.

The old Roslindale station was raised to the new grade of the tracks and a new station constructed on the opposite side, and station grounds on each side were graded and surfaced.

La Grange street, at West Roxbury, was widened 10 feet on the north side to 60 feet, and depressed at the railroad about 14 feet. Spring street was widened 20 feet on the north side to 60 feet by the decree, and before much grading had been done the street was again widened by the city to 80 feet. The street was constructed at the latter width. It was depressed at the railroad about 15 feet. La Grange and Spring streets had maximum grades on the approaches of 4 per cent. The railroad was raised at La Grange street 4 feet, and at Spring street 3 feet, and carried over these streets by two span plate girder bridges, supported upon abutments and middle stone piers. The bridge carrying the railroad over the private way called Cass street was replaced by a new plate girder bridge, resting upon new abutments spaced 33 feet apart. The abutments at Spring street were built upon broad foundations of concrete, resting directly upon quicksand. At Cass street a pile foundation was put in.

The new street at Roslindale, La Grange street and Spring street, and the connecting streets, changed to meet the new grade of these streets, were surfaced with granite block gutters and macadam roadways. Considerable difficulty was experienced in macadamizing Spring street, fully double the contemplated amount of broken stone being put upon the subgrade, which was quicksand, in order to make a satisfactory pavement.

A new station was built on the westerly side at West Roxbury and the old easterly station raised up to the new grade. At Spring street the two main tracks were spread apart and an island station, so-called, was constructed between them, with a long platform connecting by stone steps with Spring street and Cass street. A freight yard was constructed on the westerly side of the railroad south of Cass street. The railroad, where changed in grade, was laid with two new 100-pound steel rail tracks.

As a substitute for all the private crossings on the West Roxbury branch between Spring street and Dedham a 30-foot street was constructed on the westerly side of the railroad, extending

from Belle avenue to Washington street in Dedham. This street was carried over Mother Brook by a wooden truss bridge resting on piles.

WORK ON THE DEDHAM BRANCH.

The Dedham branch, which was a double-track branch, was lowered at Walnut street 5 feet, and at Mt. Vernon street about 6 feet. At East street it was raised about 2 feet. The total length of change of grade on the branch was 6300 feet. Between Walnut street and Mt. Vernon street the railroad was in quite a deep rock cut, and in lowering the tracks about 6 feet it was necessary not only to take out the rock under the tracks, but also to widen out the slopes. One track was lowered at a time, the other track being used as a single track between Dedham and Readville. The excavated material was hauled away in small dump cars by a small narrow-guage locomotive, the average haul to the dump being about three-quarters of a mile. Walnut street freight yard was lowered to meet the new grade of the branch and the tracks relaid. Where changed in grade, the branch was constructed with two new 100-pound steel rail tracks.

A heavy retaining wall, about 700 feet long, was built on the southerly side of the branch between Walnut Hill and Stone Haven stations.

Walnut street was raised 15 feet, and Mt. Vernon street 14 feet, and they were carried over the branch by plate girder bridges with plank floors. The abutments were built plumb, with cut face stone and rubble backing laid solid in cement mortar, and the wings, where carried out to retain the embankment slopes, were battered $\frac{1}{2}$ inch to 1 foot, the faces at the heights of the abutment bridge seats being in line with the faces of the parapets, and the lines of the wings making angles of about 17° with the lines of the abutments.

East street was depressed at the railroad 14 feet, and the railroad was carried over it by a four-track plate girder bridge spanning the whole width of the street. The abutments and wings were built plumb on the face.

The street approaches to all the bridges were surfaced with cobblestone gutters, macadam roadways and tar concrete sidewalks, the maximum grade on them being 5 per cent.

New wooden island stations were built between the two main tracks at Walnut Hill and Stone Haven, the tracks being spread to permit it, and a wooden stairway was constructed at Walnut Hill connecting with the Walnut street bridge, and one at Stone Haven connecting with Mt. Vernon street bridge.

THE WORK AT READVILLE IN HYDE PARK.

Fig. 12 is a general plan of the work at Readville. Near Readville station, in the town of Hyde Park, Milton street crossed at grade the Midland division (formerly the New England Railroad); about 60 feet further west it crossed above the Providence division main line, and about 360 feet west of this latter place it

FIG. 13. HYDE PARK AVENUE GROINED ARCH, READVILLE.

crossed at grade the Dedham branch. About 500 feet east of the Midland division crossing, Milton street was crossed at right angles by Hyde Park avenue, which ran northerly about 700 feet, then curved to the west and passed under the Midland division, then curved to the north and ran northerly toward Hyde Park station. Sprague street joined Milton street about midway between the

bridge over the Providence division and the Dedham branch grade crossing, and ran southerly, passing under the Midland division. Regent street left Milton street just west of the Dedham branch grade crossing and ran northerly nearly parallel with the Providence division main line. The Midland division passed over the Providence division about 80 feet south of Milton street.

This combination of grade crossings, under crossings and over crossings made it a very expensive matter to abolish the two grade crossings of Milton street. Hyde Park avenue was discontinued where it crossed the Midland division and relocated, beginning at its junction with Milton street and running northwesterly 60 feet wide, passing under the Midland division and curving to the right and then running northeasterly, passing over the electric track connection bridge to the old location of Hyde Park avenue.

Milton street was discontinued from Prescott street to Regent street and relocated, beginning at the new location of Hyde Park avenue about 350 feet north of where it passed under the Midland division and running westerly 60 feet wide, passing over the Providence division main line, the Midland division connection tracks and the Dedham branch tracks, then turning and running southwesterly 50 feet wide to the old junction of Milton and Regent streets.

Sprague street was relocated, beginning at the old junction of Milton and Regent streets and running southwesterly 50 feet wide, passing above the Dedham branch and the Midland division to its old location.

The Midland division was carried over Hyde Park avenue by a stone arch of 78 feet span and 165 feet length and a clear head room at the center of 15 feet. Nine tracks were carried over the arch. The foundation was of piles, driven in quicksand and cut off about $11\frac{1}{2}$ feet below the street grade. The spring of the arch was 8 inches above the street grade and 9 feet back from the street line, thus giving an economical distribution of masonry with a maximum resistance of foundation. The ring stones were 2 feet 6 inches deep, except on the face, where they were made deeper for better architectural effect.

The upper surface of the arch and backing was water-proofed with four thicknesses of tarred paper thoroughly mopped with tar and covered with 3 inches of tar concrete. Passing on a skew through the southerly haunch of the arch, there were constructed two arched stairway openings, 8 feet wide, leading up to platforms between the Midland division passenger tracks. Particular care was required in designing the groined arch stones for these stair-

way openings. Fig. 13 shows the groined key at one of the openings being set, and Fig. 14 gives a more general view of the opening and of the partially-constructed arch. The westerly face of the arch was constructed at an angle of 77° 52′, and the easterly face at an angle of 61° with the axis of the arch, with necessary spandrel face walls capped with a dressed coping.

Milton street was carried over the Providence division by a two-span plate girder bridge, supported upon abutments and an intermediate stone pier. The easterly span was 96 feet and the westerly one 104 feet. The easterly and part of the westerly spans

Fig. 14. Hyde Park Avenue Arch, under Construction, Readville.

were on a grade of 5 per cent., the rest of the westerly span being level, and there were vertical angles in the girders about 12 feet west of the pier, a somewhat unusual construction. The abutments were plumb on the face, the wings battered ½ inch to a foot and constructed at an angle of 26° 34′ with the line of the abutments. The pier was battered on all sides. The bridge was at right angles, and the masonry was typical of the masonry for overhead bridges.

Sprague street was carried over the Dedham branch and the Midland division by two spans of a through pin-connected steel truss bridge, each span being 223 feet long, supported upon abutments and a middle pier similar to the masonry at Milton street,

but on a skew and considerably higher, especially the pier, which was 50 feet high from the bottom of the foundation to the top of the bridge seat. The southerly span was constructed on a grade of $2\frac{1}{4}$ per cent., and the northerly span on a grade of 5 per cent.

A plate girder bridge of short span carried Hyde Park avenue over the proposed electric track connection between the two divisions.

The street approaches to these overhead bridges were on high earth embankments, the earth being brought from Sharon on cars, dumped near the work and hauled into place in carts; and they were all finished with granite block gutters and macadam roadways. The total length of streets resurfaced at Readville was 5500 feet, a little over one mile.

The Midland division was carried over the Providence division by a new five-track through pin-connected steel truss bridge of 129 feet span, with necessary masonry abutments.

A new large two-story brick station, with necessary covered platforms, was built near the crossing of the Midland and Providence divisions, the lower story being at the level of the Providence division main tracks and the upper story at the level of the Midland division tracks. A long subway, passing under nine tracks on the Providence division, was constructed with abutments of rubble masonry faced with enamel brick, with necessary stone stairways leading to covered platforms between the passenger tracks, and with a covering of solid steel troughs. Most of its length, the subway was built on a grade of 4.3 per cent., and at the lowest place the floor was about $5\frac{1}{4}$ feet below the ground water level. To make this water-tight, a water-proofing of ten thicknesses of thoroughly mopped tar paper, protected by a sufficient thickness of concrete on each side, was carried under the whole subway and brought up on the sides and ends to meet the water-proofing put on top to shed rain water, etc. To make doubly sure of keeping this subway dry, a drain was laid from the subway to an 18-inch drain pipe which was laid down to the Neponset River.

Large and convenient station grounds on both sides of the Providence division were graded and surfaced.

The Midland division was raised at Hyde Park avenue 3 feet, and depressed at Sprague street about $1\frac{1}{2}$ feet, it being changed in grade for a length of 5000 feet. Five steel tracks were laid where the grade was thus changed. On the Providence division main line, two additional tracks were laid, making four in all, from a point about 800 feet north of the Readville station, where the four tracks at that time terminated, to a point about a mile south of it,

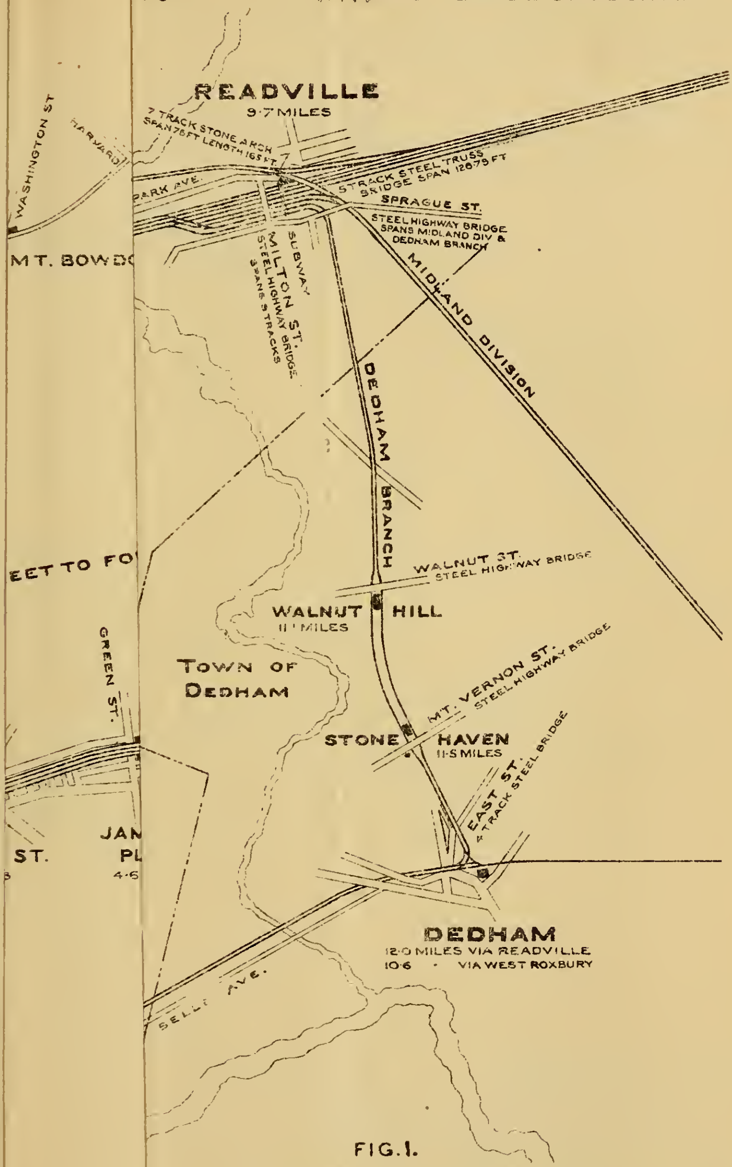


FIG. 1.

NEW YORK, NEW HAVEN, & HARTFORD RAILROAD. 496

MAP OF THE BOSTON READVILLE
AND DEDHAM CIRCUIT.

FOREST HILLS OFFICE BOSTON. MAY 1899.

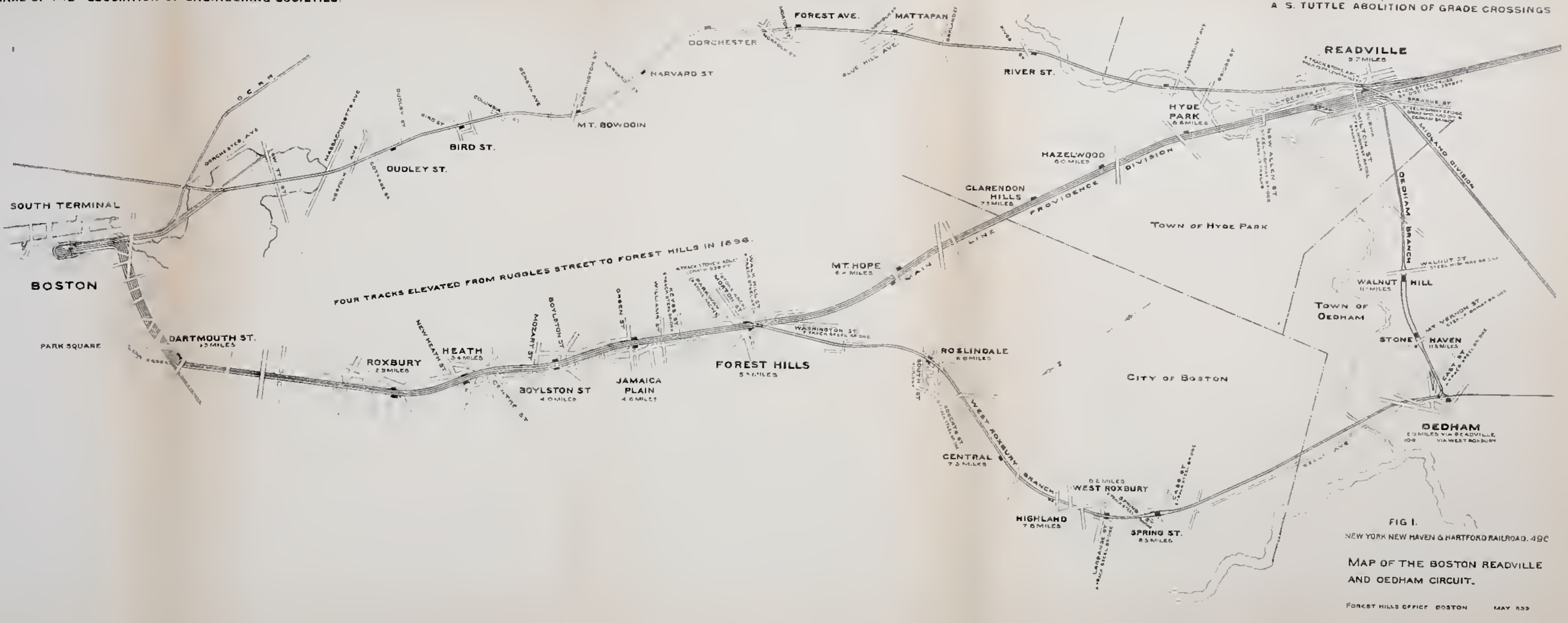


FIG I.

NEW YORK NEW HAVEN & HARTFORD RAILROAD.

MAP OF THE BOSTON READVILLE AND DEDHAM CIRCUIT.

S. TUTTLE ABOLITION OF GRADE CROSSINGS.

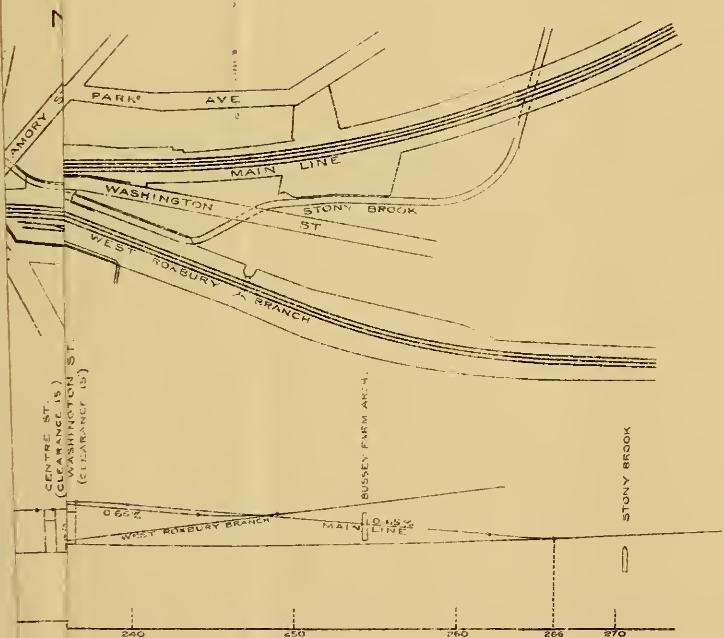
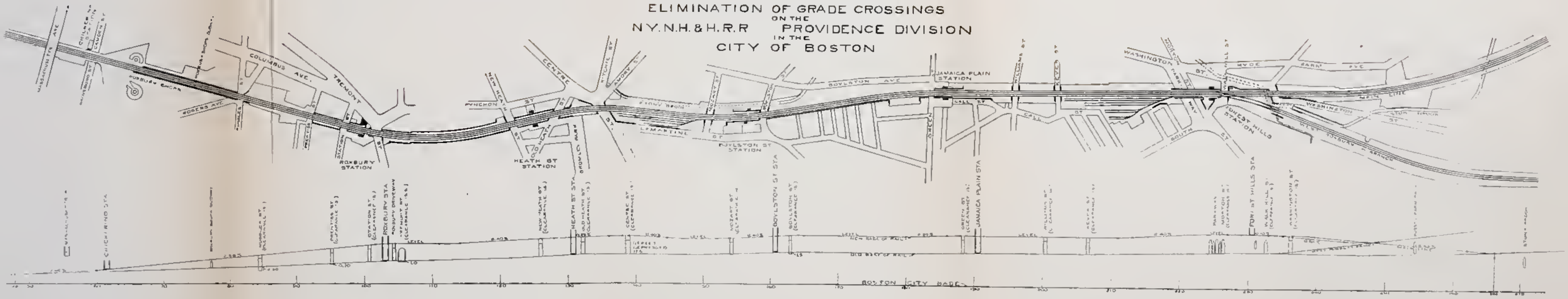
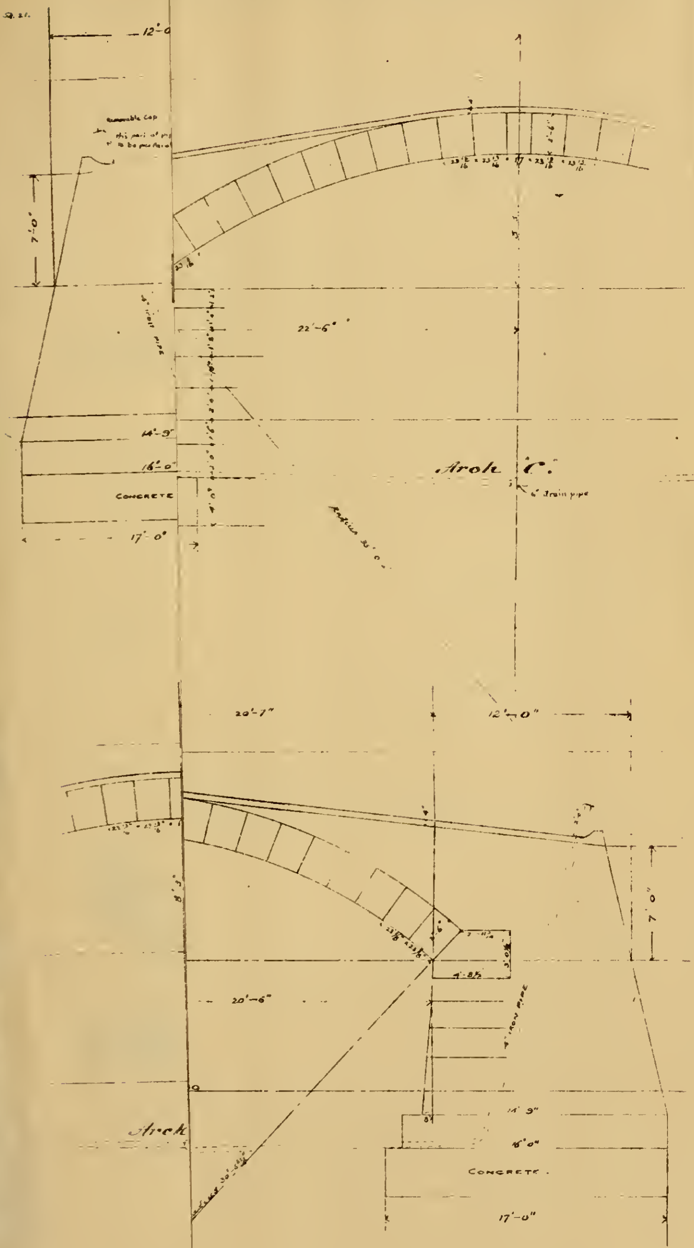


FIG 3.

PLAN AND PROFILE OF THE
ELIMINATION OF GRADE CROSSINGS
ON THE
N.Y.N.H.&H.R.R PROVIDENCE DIVISION
IN THE
CITY OF BOSTON



JOURNAL - ABOLITION OF GRADE CROSSINGS.



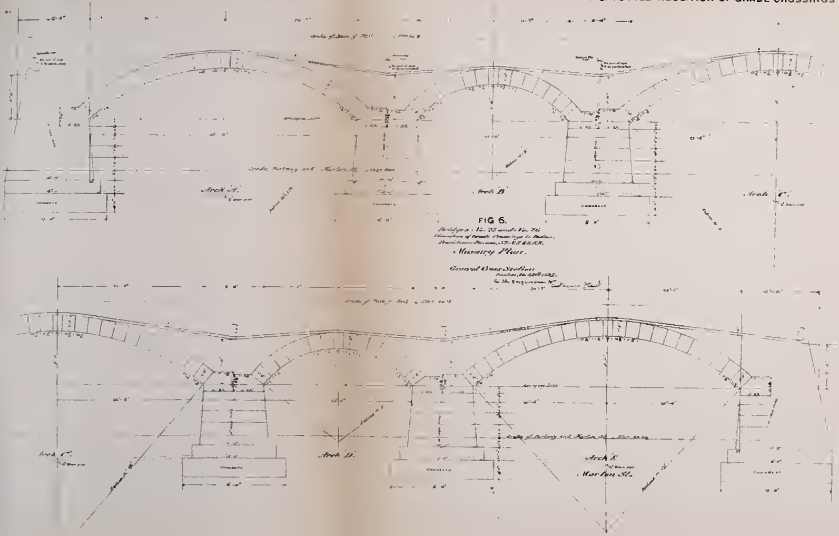


FIG 6.

FIG. 12.

N. Y. N. H. & H. R. R. PROV DIV

TRACKS AND CROSSINGS
AT READVILLE AND VICINITY.

BOSTON FEB 1899

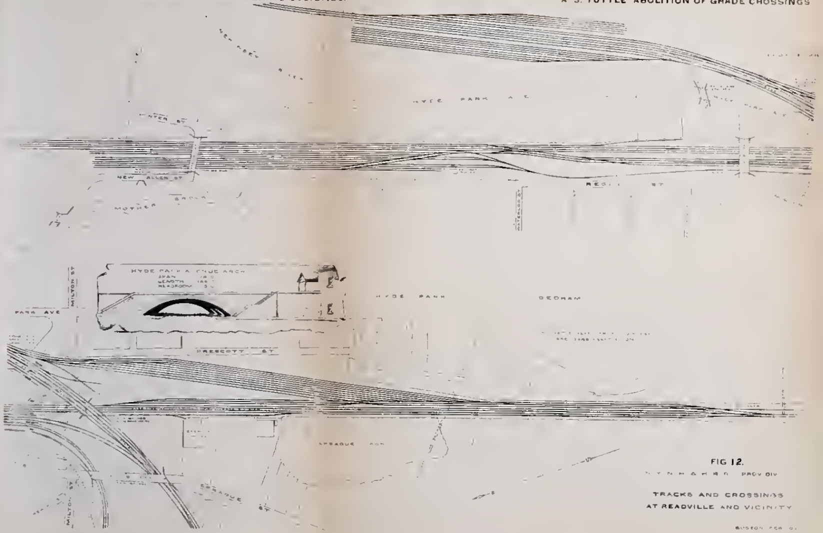


FIG 12.

N. Y. N. H. & H. R. R. PROV. DIV.

TRACKS AND CROSSINGS AT READVILLE AND VICINITY

the line and grade remaining unchanged. Two new passenger connection tracks were laid from a point on the Providence division about 1800 feet north of the Readville station to a point on the Midland division under Sprague street bridge. The Dedham branch was changed in alignment, and two new tracks laid so as to pass under the new Milton street and Sprague street bridges. The old freight yard on the Providence division was abandoned to make way for the new passenger tracks, and a new freight yard constructed north of Regent street. Large interlocking towers, one on each division, were constructed for the safe handling of switches, signals, etc. A freight connection and transfer yard between the two divisions were constructed south of the new station.

About half-way between Readville and Hyde Park stations, the new street, 40 feet wide, was constructed, passing over the Providence division and the new freight yard by a two-span plate girder bridge, spanning fourteen tracks. One span was 114 feet, and the other 94 feet. The masonry was similar to that at Milton street. Approaches to this bridge, 600 feet long on the easterly side and 1100 feet long on the westerly side, were constructed with cobblestone gutters and macadam roadways. A brick arch of 20-foot span, with stone abutments, was constructed under the westerly approach to allow access from the railroad to Mother Brook. The exposed ends of this arch were finished with granite ring stone and spandrel face walls. This westerly street approach was carried over Mother Brook by a plate girder bride supported upon masonry abutments.

About 24 acres of land were taken or purchased in connection with the abolition of the grade crossings on the Dedham and West Roxbury branches and at Readville.

The final estimates of work done by the contractors on this work were submitted in February and April of 1899, about fifteen months after the beginning of the work. The cost of this work was $2,020,894, making a total cost for abolishing all the grade crossings on the Providence division between Boston and Dedham $6,062,408.

All the work on the West Roxbury and Dedham branches and at Readville was done under the personal supervision of Mr. George R. Hardy, assistant engineer of construction.

The chief engineer, during the entire construction of the work from Boston to Dedham, was Mr. F. S. Curtis, who is now the fourth vice-president of the railroad company.

THE SEWERAGE OF NEW ORLEANS.

By W. T. Crotts, Member Louisiana Engineering Society.

[Read before the Society, ———*]

That a city having attained the proportions of a metropolis should be entirely without one of the most necessary accompaniments of sanitation and municipal progress in this progressive age must be a source of surprise to other communities. That New Orleans has been sadly derelict in this respect is, however, only too true, and the causes thereof are perhaps not hard to find. Much is doubtless due to the character and influence of its earlier citizens, reflecting the conservative spirit displayed toward many municipal improvements, and some to the cosmopolitan character of our population; but the main and controlling factor was the deep-rooted conviction, so fondly cherished by many and not yet thoroughly eradicated from the minds of all, that the successful construction of any underground structure, extending to any depth, was an impossibility and foredoomed to failure. The soil was so much worse and the conditions so entirely different from those of any other community that this belief came to be with many a matter of local pride, and could not be relinquished without a tinge of regret and doubt.

The first recorded progressive step toward sanitary improvement came in the form of a suggestion of underground sewers from Dr. Barton, in 1850. His appeal, however, seemed to have awakened no response. The horrors of the epidemics of 1853 aroused the citizens apparently to the absolute necessity of effective measures to protect them from a recurrence of such calamities as had visited them in the past, finding their culmination in the year just closed. A sanitary commission was appointed to consider the adaptability of a sewerage system to the conditions existing in New Orleans, and the inauguration of a system of quarantine. Quarantine was established, but sewerage was again relegated to oblivion until the breath of pestilence once more swept over the city and left its inhabitants prostrate and discouraged, but still undaunted.

After the yellow fever epidemic of 1878 the desire for proper sanitary measures became stronger. There appeared, however, the great obstacle of the financial inability to meet the obligations necessary to secure the desired improvements, and the question of undertaking and operating sewerage and drainage by private capital was agitated. The Legislature passed an act giving to municipalities

*Manuscript received October 23, 1901.—Secretary, Ass'n of Eng. Socs.

the authority to grant the necessary franchises and rights to corporations or individuals to undertake these functions. Under the authority of this act, the City Council, in April, 1881, after much discussion and many protests, entered into a contract with the New Orleans Drainage and Sewerage Company for the performance of certain drainage work and the establishment of a sewerage system, the compensation for the latter to be laid upon the property owners or tenants connected therewith. Under the terms of this franchise, the territory from Louisiana avenue to Enghein street and between the river and Rampart street from Enghein street and Washington avenue, and the river and Carondelet street from Washington to Louisiana avenue, was to be sewered within five years, and the system thereafter extended into other portions of the city.

Under this grant a plan was drawn up embracing a circular sewer 6 feet in diameter, lying along Rampart street from Esplanade to Washington avenues, at an average depth of about 13 feet below the surface, and having so slight a fall as to be practically flat. Into this main sewer were to enter sewers draining the territory prescribed in the contract. At or near the corner of Esplanade avenue and Rampart street a pumping station with a capacity of 30,000,000 gallons in twenty-four hours was to be located, discharging the sewage into the river near the foot of Esplanade avenue and at a safe distance from the shore. Owing to dissensions in the company, this important work was never undertaken, and the opportunity for its early construction was lost.

Again, in 1892, private enterprise sought the privilege of sewering the city, and on March 22 of that year the City Council passed an ordinance granting such a franchise, which was transferred to a corporation organized under the name of the New Orleans Sewerage Company. This was practically a renewal of the franchise of 1881, excepting that the limits were extended in the rear to Claiborne street between Lafayette avenue and the New Navigation Canal. As usual with enterprises of this magnitude and importance, many plans and ideas were suggested for the proper solution of the problem confronting the company, and a brief reference to a few of these may not be without interest.

First, by request, there was submitted a design for the sewerage of this area by what is commonly designated the Shone system. As is doubtless well known to all, this involves no departure from ordinary practice in sewerage design, so far as local collection of sewage is concerned. The territory is divided into smaller local drainage areas, each with a central well or ejector station, in which the sewage collects, and from which it is automatically discharged

through force mains into its outlet by compressed air. This plan, while presenting considerable economy of first cost as applied to the five-year limit, when extended throughout the entire city failed to maintain this advantage. This fact, taken in connection with the great amount of perishable material and the increased cost of operation, resulted in the ultimate rejection of the plan.

What may be termed the siphon scheme was also presented and seriously urged for adoption. This plan involved the collection of the sewage in local wells, and its transportation from them to a central pumping station through iron siphons of suitable size, laid upon a hydraulic grade of 1 : 500, the final receiving well being some 40 feet in depth. The numerous obstacles to its safe and certain operation, in connection with the many complications that would arise in the extension of this plan beyond the five-year limit, were insuperable obstacles to its consideration.

A modification of the siphon plan consisted in the laying of a steel pipe of suitable size below the bottom of the lowest sewer. The sewage was to be collected into local wells and delivered into this steel pipe through air-tight gates or valves. This main was equivalent to a large and lengthy suction pipe, with numerous branches extending to the various local wells, and presented the same serious objections as the siphon project.

Nor must we omit, in passing, the scheme whereby the sewage, after collection, was to be discharged into the Mississippi River at a velocity of 1500 feet a second. No plan, however, was presented for the protection of the shipping in the harbor in the event that any vessel should be so unfortunate as to get within range of this discharge.

In the plan finally adopted the sewage was gathered into a main sewer in the rear and delivered to a pumping station located on the site of the old Parish Prison, at the corner of Marais and Orleans streets, with an outlet into the river at the foot of Esplanade avenue. This main sewer, while designed sufficiently large to handle all the sewage up to and including Carrollton, would still, for many years to come, have but a small proportion of its ultimate flow to care for, and was therefore made oval in shape. The system was to have been mainly flushed from a surrounding flushing main, and from such flush tanks as were necessary where the flush main was not available. Under this plan, after much delay and many discouragements, work was finally started. Thirty-six hundred feet of main sewer and several miles of pipe sewers were constructed before financial disaster overtook the enterprise, and the prospect of immediate sewerage again vanished. But the

leaven was working, and, with the growing sentiment in favor of sewerage, the demand that this and other public improvements should be under municipal control also increased. Then began that magnificent popular movement, which is recent history, and which resulted in the means being devised whereby the city could construct and operate its own public works. Under the legislation resulting from this movement, sewerage plans have been formulated, and it is of these that this paper treats to-night.

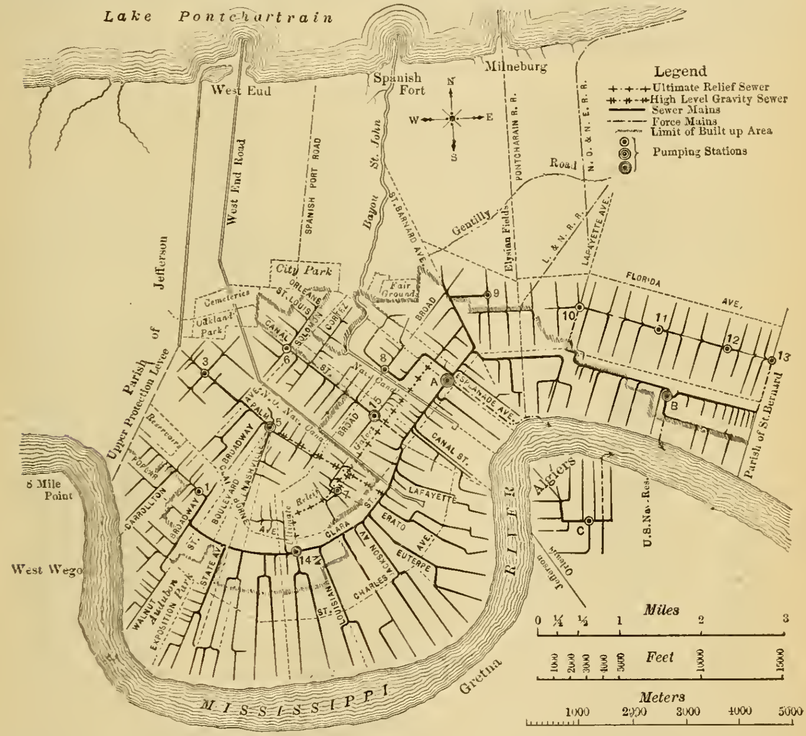


FIG. I.

In the design of the sewerage system for this city no startling or novel departures have been employed or attempted. Well-known and accepted principles, such as have stood the test of years of practical use and operation, have been the basis, the interests at issue and the amounts involved being too large to trust to untried methods, however correct and adaptable in theory.

AREA COVERED.

The act creating the Sewerage and Water Board provides that contracts for construction should be so let as to cover the whole city at the same time, further defining the whole city to mean that

inhabited portion now divided into squares and lots, where the streets are open and in use as such, or whenever hereafter opened and in use. The plans as drawn, therefore, had in view the immediate sewerage of the built-up portions of the city, with extensions of the system to meet future growth. They embrace all the territory from the upper Protection levee to the Barracks, and from the river back to Metarie road, Gentilly road, Marigny avenue and Florida walk, and also Algiers, an area of 22.9 square miles. These plans embrace some 900 miles of sewers, of which about 400 miles are for immediate construction. In Fig. 1 the

TABLE I.

Population per Acre in Areas of Greatest Density in Various Wards.

Ward.	Area Acres.	No. of Premises.	Premises per Acre.	5 Persons per Premise.		As Shown by Census.		
				Total Populat'n at 5 per Premise.	Populat'n per Acre.	Populat'n per Premise, whole Ward.	Total Populat'n.	Populat'n per Acre.
1	51.0	622	12.2	3110	61.0	4.72	2936	57.5
2	112.0	1059	9.4	5295	47.3	5.40	5718	51.0
3	63.0	892	14.2	4460	70.9	4.46	3978	63.1
4	63.0	757	12.0	3785	60.0	3.96	2998	47.6
5	93.0	1258	13.5	6290	67.6	5.52	6944	74.6
6	84.0	961	11.4	4805	57.2	5.29	5084	60.5
7	63.0	881	14.0	4405	70.0	5.13	4519	71.7
8	59.5	896	15.0	4480	75.3	4.71	4220	71.0
9	22.5	309	13.7	1545	68.7	6.14	1897	84.1
10	131.5	1644	12.5	8220	62.5	4.64	7628	58.0
11	116.0	1400	12.1	7000	60.3	4.71	6594	56.9
12	193.5	1556	8.0	7780	40.2	5.13	7982	41.9
13	68.0	628	9.2	3140	46.2	5.39	3384	49.8
14	45.0	201	4.5	1005	22.3	6.51	1308	29.2
15	48.0	368	7.7	1840	38.3	6.67	2454	51.1
16	20.0	102	5.1	510	25.5	5.66	577	28.8
17	42.5	234	5.5	1170	27.5	5.55	1299	30.5

area between the hatched line and the river represents the present inhabited area, which is to be sewered immediately, and which covers 13.8 square miles; while that portion in the rear is not yet built up, but must be provided for in the general plan.

POPULATION.

After fixing the territory to be covered in the plan the next most necessary and essential factor was the determination of the population, both that existing at present and that to be provided for in the future; also the disposition and varying densities of such population in different portions of the city. A decade having elapsed since the last government census, it became necessary to turn to other sources of information. A count of all the premises

within the inhabited area was made from the insurance maps, showing a total of 56,423 within this territory. Assigning five persons to each, this gave an existing population of 282,115. The government census, taken the following month and promulgated some time thereafter, gave to the entire city a population of 287,104, or 5000 in excess of that which we estimated. The government census, however, covered the entire parish, including West End, Milneburg, etc., and the scattered houses outside the limits computed by us, and which would easily cover this difference. This estimate of 282,113 gave an average of 31.9 persons to each

TABLE II.

Reduction of Flow to Cubic Feet per Second per Acre. To Apply only to Areas under 200 Acres.

Area.	Total Acres in Area.	Estimated Population per Acre.	House Drainage per Acre.			Ground Water Cubic Feet per Second per Acre.	Total Cubic Feet per Second per Acre.
			Gallons in 12 Hours.	Cubic Feet in 12 Hours	Cubic Feet per Second.		
A	642	50	4000	533.3	.012	.003	.015
B	1618	55	4400	586.7	.014	.003	.017
C	869	60	4800	640.0	015	.003	.018
D	500	80	6400	853.3	.020	.003	.023
D1	561	115	9200	1226.7	.028	.003	.031
E	515	80	6400	853.3	.020	.003	.023
F	432	70	5600	746.7	.017	.003	.020
G	479	70	5600	746.7	.017	.003	.020
H	323	70	5600	747.7	.017	.003	.020
I	437	70	5600	746.7	.017	.003	.020
J	532	70	5600	746.7	017	.003	.020
K	834	50	4000	533.3	.012	.003	.015
L	519	50	4000	533.3	.012	.003	.015
M	200	50	4000	533.3	.012	.003	.015
N	378	50	4000	533.3	.012	.003	.015
	8839						
O	5744	50	4000	533.3	.012	.003	.015

acre in the inhabited portions of the city, varying from 8.9 per acre in the sparsely built sections to 58.3 per acre in the older portions of the city immediately below Canal street. Taking the number of premises in each ward by actual count and the population as given by the census, it was found that the number of persons to each premise varied from 3.96 each in the Fourth Ward to 6.67 each in the Fifteenth Ward. · With these figures upon which to base an estimate, the greatest density of population in each ward over a limited area was found to vary from 28.8 per acre in the Sixteenth Ward to 84.1 per acre in the Ninth Ward, as shown in Table I.

Having ascertained the present population, and taking into consideration the probable direction and density of future growth, the next problem was the determination of the future population

which must be dealt with, and for which sewerage facilities must be provided. After a careful consideration the city was divided into a number of areas, and a density of population assigned to each as a basis upon which to base the estimate of flow. These estimates of future population are shown in Table II, varying from 50 per acre in the residential sections to 115 per acre in the more thickly built-up portions, giving, upon this basis, an ultimate population of 856,000 within the area covered by present plans. With an annual increase of 20 per cent., this population would be reached in 1960.

TABLE III.

NUMBER OF ACRES DRAINED IN EACH "POPULATION AREA" BY PIPE SEWERS LAID ON MINIMUM GRADE EMPLOYED IN PLAN.

8″–18″ inclusive to run half full .... n = .011.
21″–24″ " " .7 " .... n = .012.
27″ and over " .7 " .... n = .013.

Size.	Grade.	POPULATION AREA.							
		A.	B.	C.	D.	D 1.	E.	F-J.	K-O.
8″	1 : 300	25	22	21	16	12	16	19	25
10	1 : 400	40	35	33	26	19	26	30	40
12	1 : 475	61	54	51	40	30	40	46	61
15	1 : 600	101	89	85	66	50	66	76	101
18	1 : 750	151	133	126	100	71	100	113	151
21	1 : 875	310	270	260	200	150	200	230	310
24	1 : 1000	410	360	345	270	200	270	310	410
27	1 : 1000	515	460	430	335	250	335	385	515
30	1 : 1100	650	575	545	425	315	425	490	650
33	1 : 1200	810	720	680	530	395	530	610	810
36	1 : 1200	1030	910	860	670	500	670	770	1030

AMOUNT OF SEWAGE.

The estimated amount of sewage to be provided for is derived from two sources,—namely, house sewage and ground water. The house sewage is based upon an estimated consumption of 80 gallons of water per capita in each twenty-four hours, with a maximum flow at the rate of 160 gallons in twenty-four hours. The ground-water flow was estimated at one-third of the annual rainfall, or 1,000,000 gallons per square mile in twenty-four hours. In the calculations used, however, this flow was taken at 0.003 cubic feet per second per acre, which would give a run-off equal to 1,250,000 gallons per square mile in twenty-four hours. In order to verify this factor permission was obtained from the sewerage company to pump out the sewers constructed several years ago and measure this flow. While this investigation did not continue through so long a period as could have been desired, it was sufficient to demon-

TABLE IV.

Acres and Flow Tributary to Front Main and Trunk Sewer at Various Points; also Proportion of Flow to Main and Size of Main.

Tributary at	Acres Drained by Sub-Main.	Total Acres Tributary to Main.	Total Flow Due to Full Discharge, Cubic Feet.	Percentage of Full Discharge Due to Enlarged Area	Cubic Feet Reaching Main.	Size of Circular Sewer Running Half Full.	Size of Circular Sewer Running .7 Full.
Plum and Broadway	1030	1030	15.45	00.83	12.82	3′–6″	3′–0″
State and Willow	425	1455	22.67	00.73	16.55	3 –9	3 –3
Peters Ave. and Clara	518	1973	31.48	62.50	19.67	4 –3	3 –6
Valence and Clara	484	2457	39.43	62 50	24.64	4 –6	3 –9
Berlin and Clara, S. S.	275	2732	43.55	62.50	27.21	4 –9	4 –0
Marengo and Clara	427	3159	50.81	62.50	31.75	5 –0	4 –3
Louisiana Ave. and Clara	382	3541	57.52	62.50	35.95	5 –3	4 –6
Washington and Clara	371	3912	64.41	62.50	40.25	5 –6	4 –9
Jackson Ave. and Clara	553	4465	74.57	62.50	46.60	5 –9	5 –0
Felicity and Clara, S. S.	401	4866	83.41	62.50	52.13	6 –0	5 –3
Melpomene and Clara	333	5199	88.40	62.50	55.25	6 –3	5 –6
Erato and Clara	302	5501	95.50	62.50	59.68	6 –3	5 –6
Calliope and Clara	31	5532	96.12	62.50	60.C7	6 –3	5 –6
Lafayette and Clara	221	5753	102.15	62.50	63.84	6 –6	5 –9
Poydras and Clara, S. S.	52	5805	103.19	62.50	64.49	6 –9	5 –9
Perdido and Clara	45	5850	104.09	62.50	65.05	6 –9	5 –9
Gravier and Derbigny, S. S.	40	5890	104.89	62.50	65.55	6 –9	5 –9
Cleveland Ave. and Derbigny, S. S.	30	5920	105.49	62.50	65.93	6 –9	5 –9
Canal, U. S., and Derbigny	178	6098	110.35	62.50	68.96	6 –9	5 –9
Canal, L. S., and Derbigny	181	6279	114.51	62.50	71.56	7 –0	6 –0
Bienville and Derbigny, S. S.	24	6303	114.99	62.50	71.86	7 –0	6 –0
Conti and Derbigny, S. S.	18	6321	115.35	62.50	72.09	7 –0	6 –0
Toulouse and Derbigny	27	6348	115.94	62.50	72.46	7 –0	6 –0
St. Peter and Derbigny, S. S.	14	6362	116.22	62.50	72.63	7 –0	6 –0
St. Ann and Derbigny, R. S.	135	6497	119.32	62.50	74.57	7 –0	6 –0

strate the fact that this estimated flow was very close to that actually obtained, being the more valuable in that it extended through several rains.

Having then determined the population per acre, the sewage per capita and the amount of ground water, there remained to combine and tabulate these factors and reduce them to a convenient form for the rapid determination of the size of sewer required for different areas. Table II shows the manner in which the run-off per second per acre from each area was reached, and Table III shows the number of acres in each of the various sections of the city that are served by different-sized sewers.

This maximum run-off per acre, as given in Table II, is intended to apply only to areas under 200 acres. As the area increases the tendency to a more uniform flow becomes more marked. It is evident also that, from sections contiguous to the point of final disposal, the sewage will have been discharged before that from the more remote portions of the system reaches this territory. For all areas over 2000 acres it was decided to proportion the sewers for a daily discharge equivalent to a per capita consumption of 100 gallons, including ground water; and that for mains and sub-mains between these limits (200 and 2000 acres) they were to be proportioned for a gradually decreasing run-off as the area increased. Fig. 2 is a set of curves showing the estimated run-off in the various sections of the city between these limits. Table IV shows the method of determining the flow and size of main sewers.

SIZE, SHAPE, ETC.

The unit of the system is a pipe of 8 inches internal diameter, and constitutes about 87 per cent. of the total mileage of the system as designed. Increasing in size as the flow increases, the largest main finally attains a diameter of 6 feet for some distance before it reaches the pumping station. Sewers up to and including 24 inches are to be of vitrified stoneware pipe, and those above that size are to be of brick. All sewers are circular, the brick sewers having a rectangular base resting upon a plank foundation. As the sewers to be built at once serve practically the whole territory for which they are designed, and, while not receiving their ultimate amount of sewage, will still have a good initial flow, it was decided to make them circular from the point of view of both strength and economy. The standard design of brick sewers is shown in Fig. 3.

All sewers up to and including 18 inches are designed to run half full. Above 18 inches, they are designed to run 0.7 full, the

larger area served insuring a more nearly constant and uniform discharge.

DEPTHS OF SEWERS.

Before entering upon the design of the sewerage system, several factors had to be considered and determined. Foremost among these was the question of limiting depths of sewers. A certain initial depth was necessary, not only to enable house connections to be laid with proper grade and alignment, but to avoid obstructions where the struggle has been with all underground

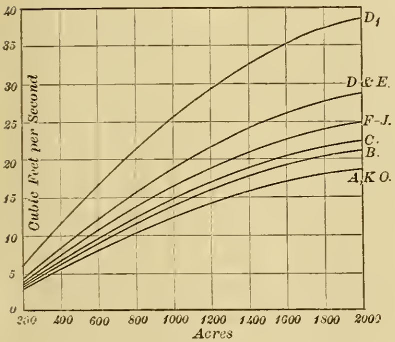


FIG. 2.

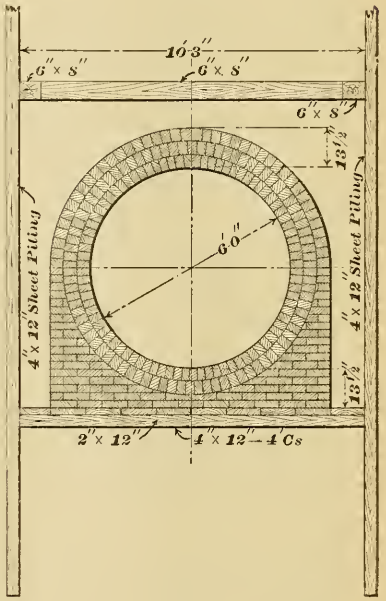


FIG. 3.

structures to keep as near the surface as possible. On the other hand, the peculiar character of the soil, saturated and plastic, where the deeper excavations threatened damage to streets, curbs and buildings, where every foot of depth meant a rapidly increasing cost, and yet a too shallow depth meant a too rapidly increasing number of dead ends and the consequent first cost and annual expense of innumerable flush tanks, the question of maximum depth assumed a position of prime importance. After carefully weighing the matter it was decided to adopt a minimum depth of 5 feet and a maximum depth for laterals of 9 feet and of sub-mains of 16 feet. For reasons of economy and efficiency, these limiting depths were not applied to main sewers.

GRADES AND VELOCITIES.

Where natural conditions contribute so little to grades, and where fall must be created by increased depths and expense, the question of minimum grades becomes of the utmost importance, and when a system of grades has been once established it must be rigorously adhered to. Economy of construction through economy of depth requires that the sewers be laid at the smallest possible inclination that will insure their efficiency and operation. Assuming the value of n, in the Kutter formula, as 0.011 for pipe sewers and 0.013 for brick sewers (because it is believed that these values can be secured by proper and careful construction), and the initial velocity of 2 feet per second, the conclusion was reached that a slope of 1 in 300 could be safely adopted for an 8-inch sewer, and the bulk of the system is designed to that grade.

Along with the disadvantages under which we labor, there are, however, some compensating features. In sewer design the usual experience is to have the steep grades and high velocities in the higher and smaller portions of the system, and the flat grades and slow velocities in the lower and larger portions, a condition leading to the formation of eddies and deposits from the sudden checking of the flow. Here, where grades and velocities are to be determined and established,—not by topography, but by calculation,—there is presented the possibility of ideal conditions in this respect. Starting with the initial velocity of 2 feet per second in the laterals, the velocity is gradually accelerated, increasing with the size of the sewer until it reaches 3.66 feet per second in the largest main. This point has been kept carefully in view throughout the entire design, and few if any instances will be found where there is any departure from it. Any material, therefore, which is capable of transportation in the smaller sewers will be pushed steadily along until it reaches the sand pit at the pumping station without being permitted to stop and form obstructions along its course.

In this connection it may not be uninteresting to trace the route and the time required for the transportation of sewage from the more remote portions of the city to the outfall. The longest distance to be traversed is from the corner of St. Charles and Carrollton avenues. Starting at this point, the sewage enters the submain at Hampson and Dante, travels along Dante to Cohn, Cohn to Lowerline, where it encounters the first pumping station and is lifted 7 feet; continuing thence along Cohn to Broadway, Broadway to Plum, across to Clara and it passes down Clara to Marengo, where it is once more picked up 7 feet by a second pumping station;

and continues along Clara to Gravier, Gravier to Derbigny and Derbigny to the main pumping station, having occupied in its subterranean journey three hours and ten minutes and traveled 6.4 miles at an average speed of 2.96 feet per second. It is not allowed to tarry here, however, but is immediately picked up by powerful pumps and forced into an iron main, from which it emerges twenty-one minutes later into the Mississippi River, three hours and thirty-one minutes after starting on its trip of 7.81 miles.

FLUSHING.

Recognizing the importance and necessity of flushing, provision has been made to flush every block of sewer. For daily flushing, reliance is placed in automatic flush tanks, located at the head of each sewer and discharging about 300 gallons in each twenty-four hours. This, however, must be supplemented by such hand flushing as may be necessary to keep the system in good order. This will be accomplished, first, by introducing, into each flush tank and at intervals into manholes along the laterals, a 2-inch pipe, which is connected directly with the water main and which can be opened full and allowed to run as long as desired. In the manholes on the larger pipe at intervals will be built simple devices which, when closed, will retain the sewage until a sufficient amount has collected to form an effective flush, when it will be released. In the main sewer flushing gates will be built at suitable distances apart, and a connection will also be made with the Navigation Canal, furnishing abundance of water for that purpose.

COLLECTION OF SEWAGE.

The alignment of the sewers and the topography of the city are so closely related that both will be considered under one head. From Esplanade avenue to the upper Protection levee, the city is practically built on radial lines, diverging toward the river with the hub far in the rear. Below Esplanade avenue there is a straight reach of river to the lower city line, the streets being laid off parallel and at right angles. The highest portion of the city is next to the river, sloping back, with a fall of as much as 15 feet in some cases to the rear, where a vast flat and level area stretches out.

In studying general methods of alignment for the collection of sewage, consideration was necessarily given to the several factors which would affect the final decision on this point. Due weight must be given to maintaining proper depths of sewers; the number of flush tanks must be kept down to a minimum, and full benefit received from those constructed; consideration has to be paid to

all existing structures, both above and below ground, to avoid conflict with them, and economy of construction and operation were quantities not to be disregarded. The fundamental basis upon

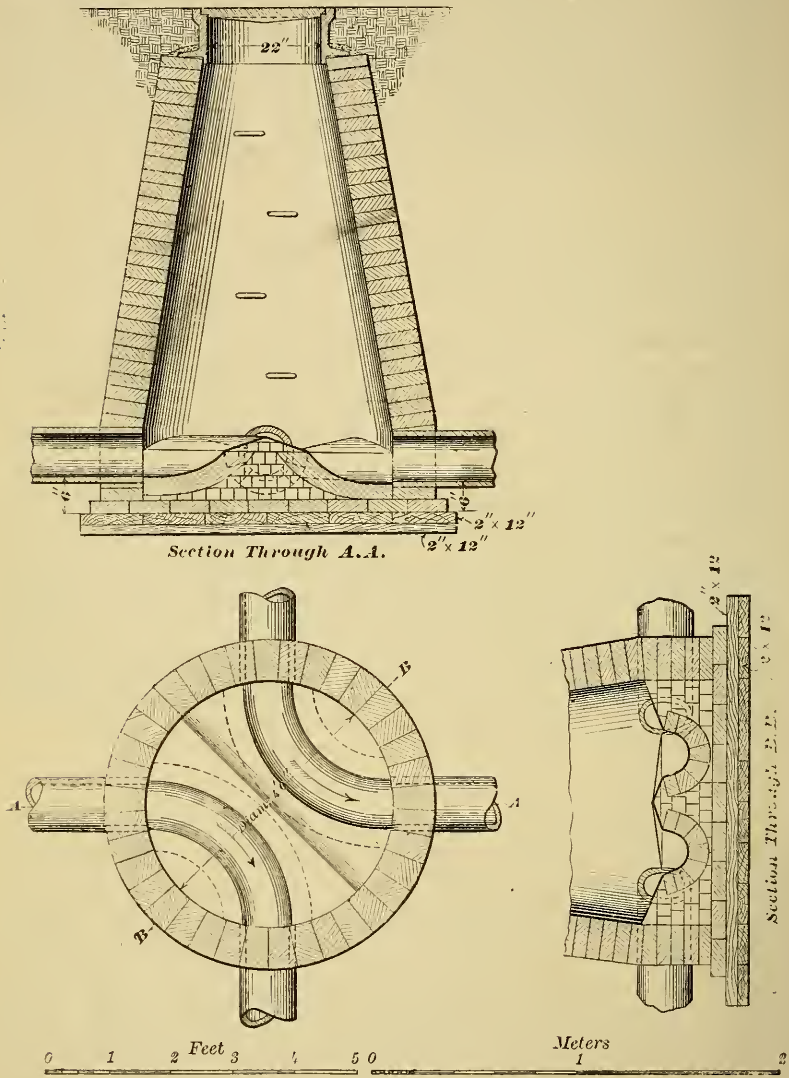


FIG. 4.

which the method for the lateral collection of sewage is based, and the dominant feature of the whole design, may be termed the rapid concentration of flow. Contrary to usual practice, the designing of the system starts at the head and works down, the use of minimum grades dictating this procedure. Selecting, at the head of the

sewer, two points as widely separated as is possible without ultimately exceeding the specified depth or making too long a distance for flush, each sewer is run alternately one block parallel with the river and one at right angles thereto, or zigzag, until a junction is effected with a sub-main or main. In this design much attention is

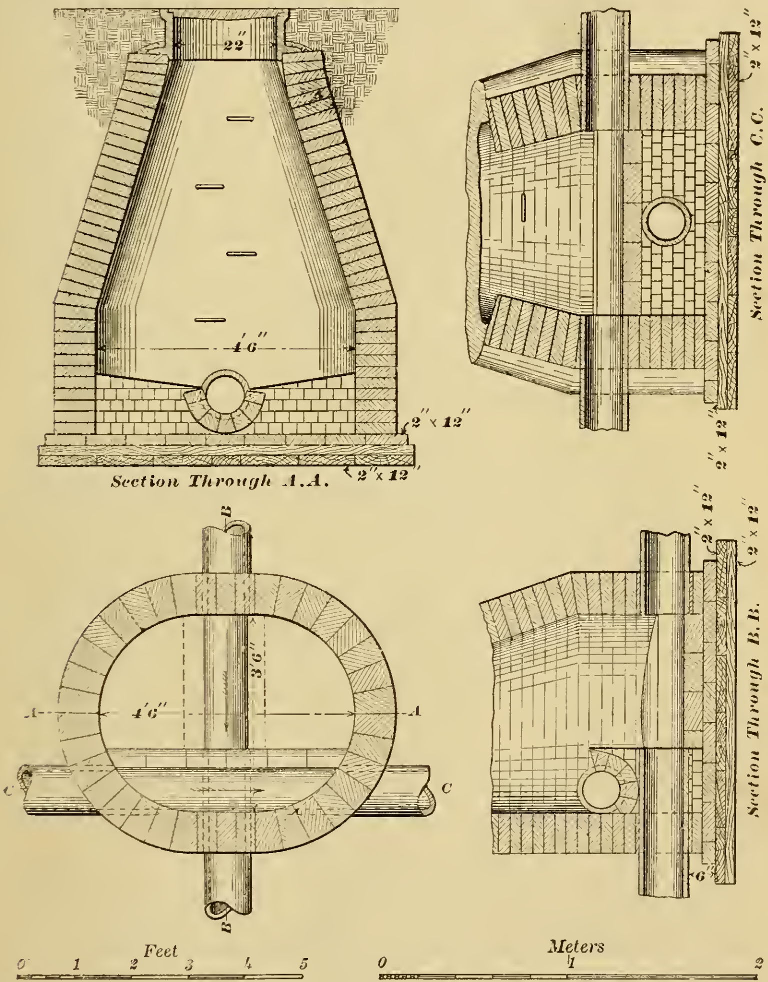


Fig. 5.

given to provision for enabling the flushing water to traverse the entire length of sewer, from the tank at its head, without the use of an excessive number of such structures. In the method of alignment adopted this is accomplished by constructing the manholes for the maintenance of distinct flow. Figs. 4 and 5 show two designs, in the first of which the sewers change their direction in

passing through the manhole, and in the second of which they pass through on a straight line. By this method the discharge from the flush tank remains in its individual line of sewer until it is emptied into the sub-main.

In the upper ends of the system, especially in that portion near the river front, all possible advantage is taken of such natural fall as exists to rapidly concentrate the sewage into sub-mains, when the smaller inclination of the large sewer serves to keep it more nearly parallel with the surface. In some cases two or more of these sub-mains unite into a still larger one before reaching the main sewer. By thus taking advantage of such slight surface slope as nature has kindly granted us, and this rapid concentration of the flow, the sewage is delivered to the main at a depth of from 10 to 13 feet, through a distance in some cases of as much as 9000 feet, without an intervening lift or pumping station. Different sections of the city naturally require different arrangements of the sub-mains without any departure from the general method of alignment and collection as outlined.

LATERAL TRANSPORTATION OF SEWAGE.

After the sewage has been collected into the sub-mains comes the question of its transportation to the main pumping stations or point of final disposal.

The peculiar contour of the city, extending for a great distance parallel with the river and of comparatively shallow depth, combined with the necessity for the discharge of the sewage below the central portion of the city and the distance it has to be transported from the upper sections, made this problem one of great importance, and the one that has given rise to the various projects which have been advanced. After a thorough and exhaustive consideration of the question in all its phases, the gravity main in the rear was selected as the most durable, efficient, certain and economical of operation. From the upper Protection levee to the Barracks stretches a line of sewers, distant in some cases 9000 feet from the river, containing in its course two main and two smaller pumping stations. Into this sewer discharges by gravity all the sewage between it and the river, and for some distance in the rear. Reaching from this main into the rear are other mains for the transportation of the sewage from those sections to the front main or pumping station direct. Through this main sewer, with never-ceasing flow, will run the sewage of the city to the point of final disposal, unhindered by the breakage of complicated machinery or the failure of perishable material.

The front main was located as far in the rear as entering sub-mains would permit, because of the greater area tributary to it by gravity. In the large uptown main also the farther in the rear the shorter will be the length to be built, the less the depth of sewer due to the lower elevation of the ground and the less disturbance to traffic and damage to streets, curbs and property in the unbuilt sections.

POINT OF DISPOSAL.

The sewage having been collected and transported to the pumping station, the point of its disposal must next be considered. A point must be selected where the sewage will not be caught up by returning eddies and carried upstream along the city's front. It must not lodge upon the shore below, or be of such quantity as to be offensive or dangerous in any way.

Taking up the latter point first, we find that few cities are so fortunately situated in this respect as New Orleans. With the waters of almost a continent sweeping by its front toward the Gulf, and no cities below dependent upon this stream for their water supply, the river presents itself at once as the safest, surest and speediest point of disposal. Assuming that a flow of 4 cubic feet per second for each 1000 of the population is necessary to sufficiently dilute the sewage as to render it inoffensive, the low water flow of the Mississippi River, based upon a discharge of 200,000 cubic feet per second, would suffice for the disposal of the sewage of a population of 50,000,000 without becoming offensive if uniformly mixed. At low water there passes each minute of the day a volume of water equal to twice the amount of sewage that will be discharged into the river at present in twenty-four hours. Looking at it still further, when the population has reached the 1,000,000 mark, with a daily discharge of 150,000,000 gallons of sewage, supposing the sewage to be 1 part solid and 99 parts water, there would be 1 part solid to 86,000 parts water, a not very alarming proportion.

Taking for granted, therefore, that the sewage will be so amply diluted as to be neither dangerous nor offensive, attention is next directed to the other points,—namely, a discharge at a point where it will be borne downstream and away from the city. To study this question satisfactorily and avoid the danger of any error, float observations were made in order to determine the lower end of the eddy and select a point whence the current does not impinge upon the bank, the proposed discharge being well out into the stream and at considerable depth below low water. Floats were started at various distances from the shore, and their course was

followed to the lower limits of the city. These observations indicated the foot of Spain street as the highest point where the sewage would be neither carried upstream nor into the bank and under the wharves below. We can assure ourselves that, when the sewage has entered the river, no further trace of it will be discoverable.

VENTILATION.

The lungs of a sewer are a very important part of its construction, for without ventilation a sewer cannot be maintained in a proper and sanitary condition. It is usual to supplement other means of ventilation by openings in the manhole covers. We cannot, however, avail ourselves of this method in the system under consideration. The large extent of unpaved streets would admit large quantities of dirt, requiring constant attention to keep the receptacles cleaned and the dirt from entering the sewers. The controlling reason, however, is the flooding of streets, which occurs with each hard shower. Each flooding over manholes would pour into the sewers, through these perforations, such quantities of water as to overload them perhaps for hours, beside bringing in large amounts of detritus to find lodgment in the sewer or manhole. To limit the operation of the sewers to the legitimate function of removing sewage only, it is evident that perforated covers must be omitted and reliance for ventilation placed upon house drains. As admission of air is necessary for the operation of the flush tank, both to insure its discharge and to prevent siphonage, special devices will be used, consisting of a pipe extending to the curb and terminating in an ornamental stand pipe.

UNDERGROUND OBSTRUCTIONS.

New Orleans apparently is no exception in the matter of underground structures and obstructions. Many of these have been laid entirely regardless of any city supervision or regulation, and where the constructing companies have so willed, and upon no well-defined plan except that of expediency. The aim of all has been apparently to seize the most available location and get as near the surface as possible, regardless of either alignment or grade, and to keep no records. While other cities have more and larger underground structures, few present more complications than New Orleans, where narrow streets cause crowding and lack of specific information renders location difficult. Much time was devoted to ascertaining the underground conditions existing in the conduit area.

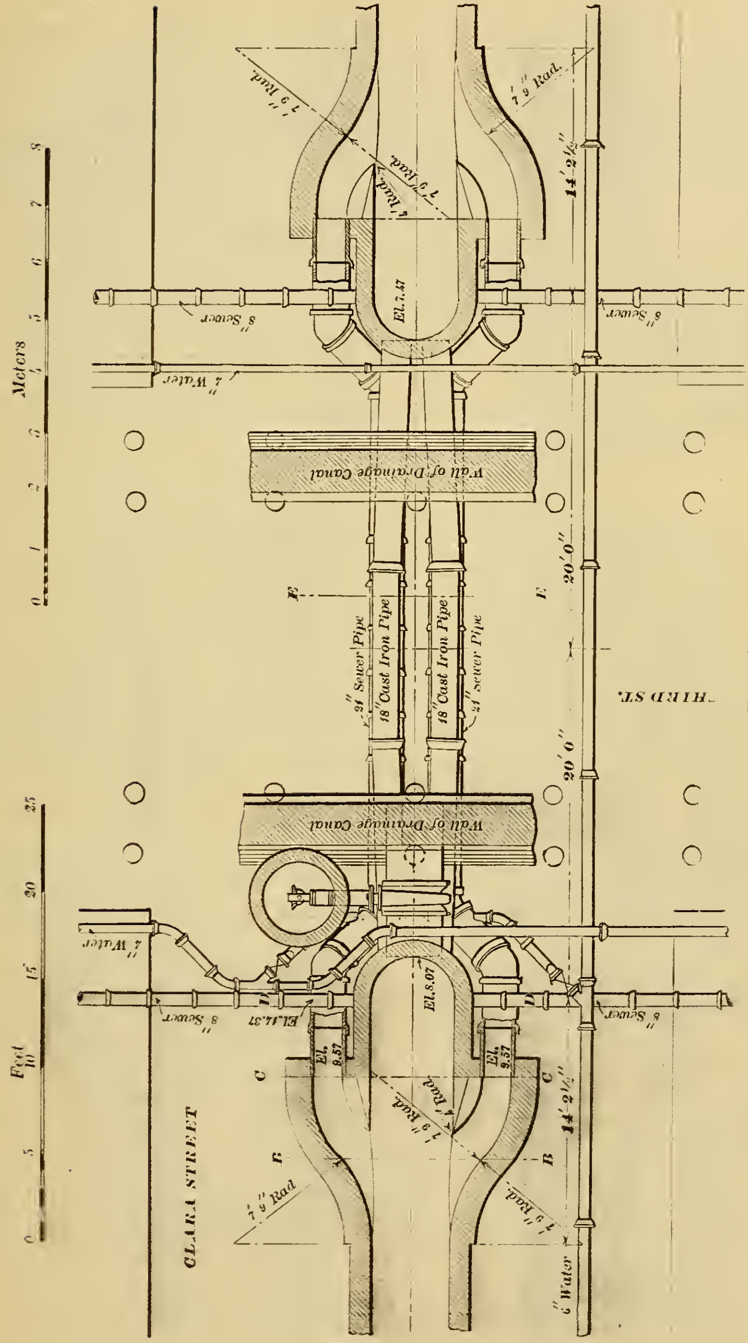

Meters
Feet
CLARA STREET
THIRD ST.
Wall of Drainage Canal
Wall of Drainage Canal
18" Cast Iron Pipe
18" Cast Iron Pipe
21" Sewer Pipe
21" Sewer Pipe
8" Sewer
8" Sewer
8" Sewer
8" Sewer
4" Water
4" Water
6" Water
El. 7.47
El. 8.07
El. 11.37
El. 9.57
El. 9.57
7' 9" Rad.
7' 9" Rad.
7' 9" Rad.
7' 9" Rad.
7' 9" Rad.
7' 9" Rad.
4' Rad.
4' Rad.
14' 2½"
14' 2½"
20' 0"
20' 0"

FIG. 6.

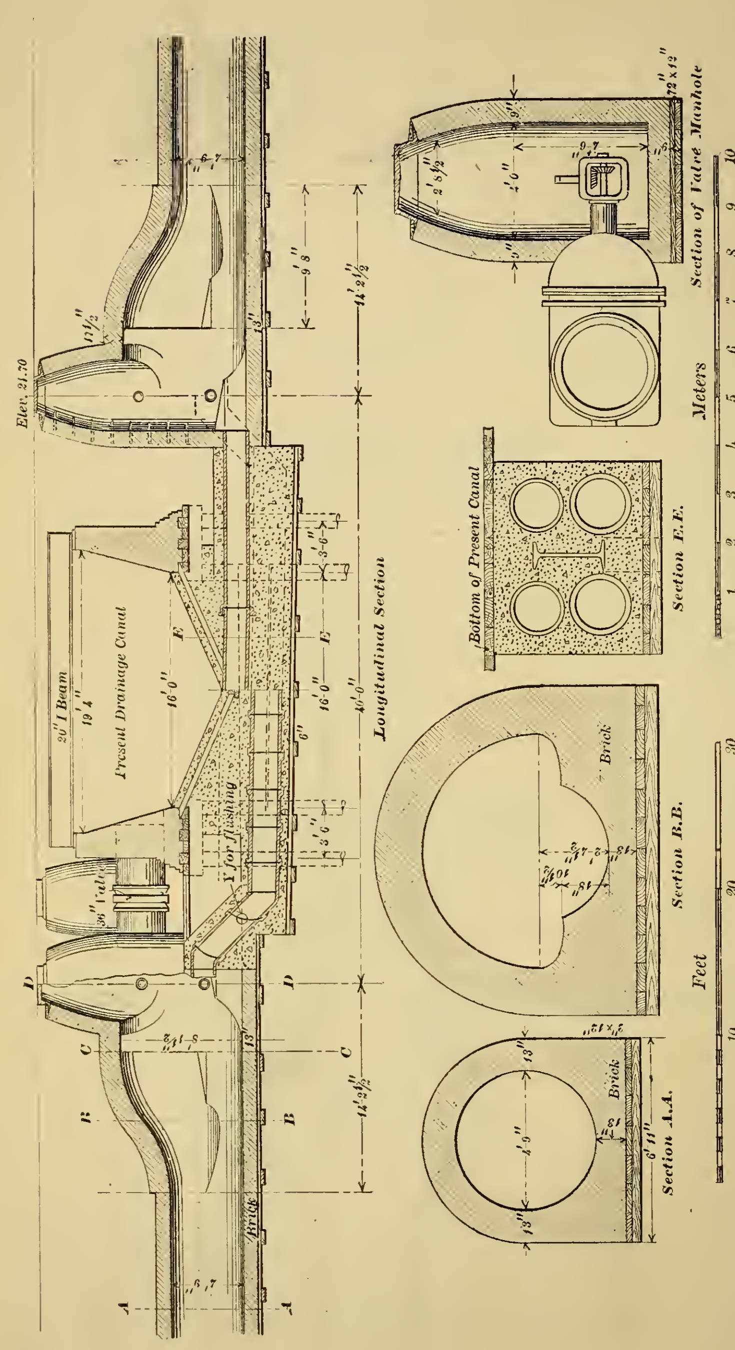

Elev. 21.70
20" I Beam
Present Drainage Canal
Longitudinal Section
Y for flushing
36" Valve
Brick
Bottom of Present Canal
Section E.E.
Section B.B.
Section A.A.
Section of Valve Manhole
Meters
Feet

FIG. 7.

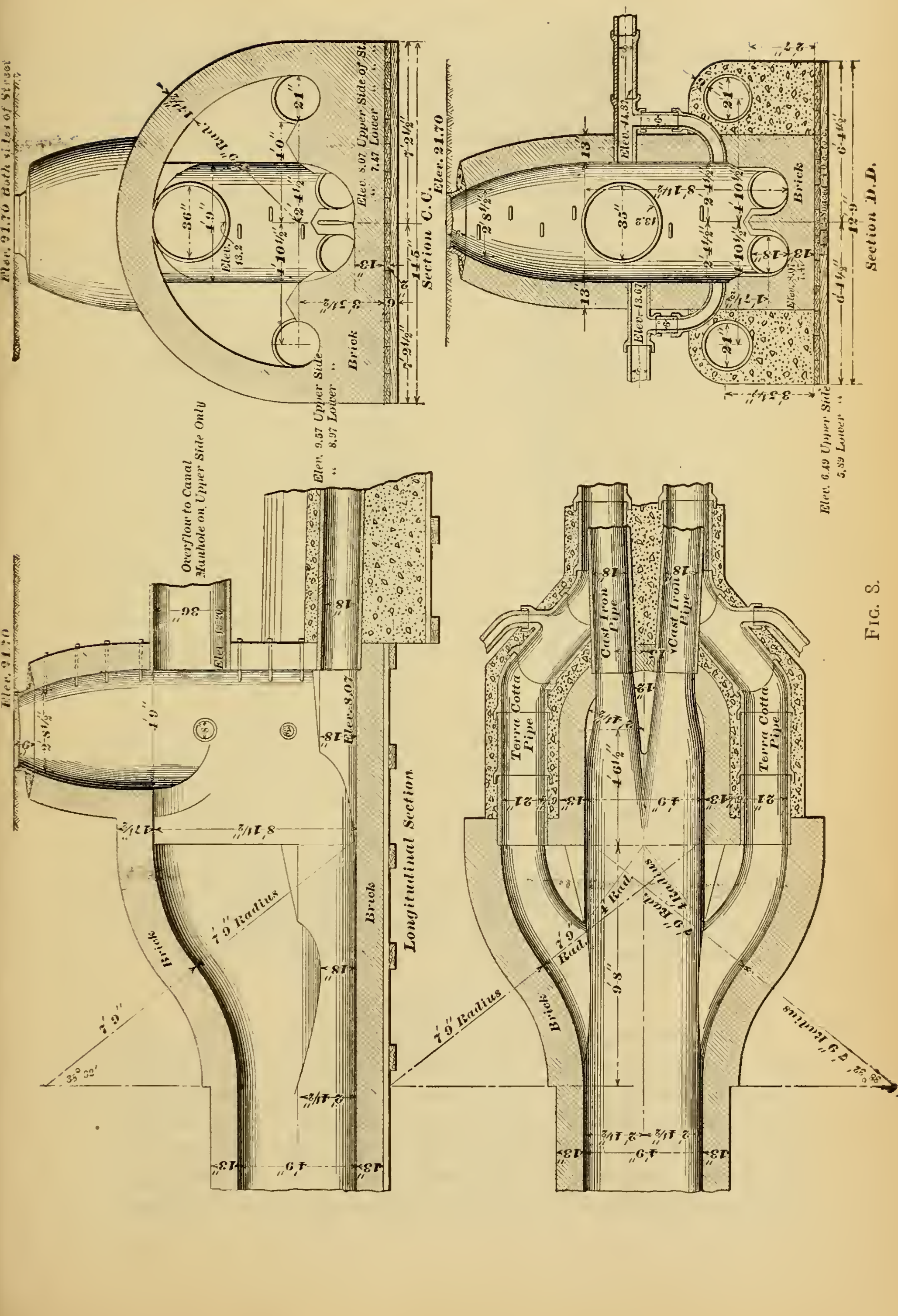

Elev. 21.70 Both sides of Street
Section C.C.
Elev. 21.70
Elev. 8.07 Upper Side of St.
7.47 Lower
Elev. 13.2
Brick
Elev. 9.57 Upper Side
8.97 Lower
Section D.D.
Elev. 14.37
Elev. 13.07
Elev. 6.49 Upper Side
5.89 Lower
Overflow to Canal
Manhole on Upper Side Only
Elev. 21.70
Elev. 8.07
Longitudinal Section
7'9" Radius
Cast Iron Pipe
Terra Cotta Pipe

FIG. 8.

SIPHONS.

Where there are so many and such large drainage canals, both existing and prospective, conflict in grades is inevitable, except by going to such a depth with sewers as would involve enormously increased cost and complications. Under such conditions, many siphons are rendered necessary, occurring mainly upon the pipe sewers near the head of the system. Owing to its great depth, one only occurs upon the uptown main sewer, and this only partially so, where the main sewer on Clara street crosses the Third street drainage canal, calling for a construction somewhat different from that of the ordinary siphons. In this case the invert of the sewer is about 21 inches below the bottom of the drainage canal. Two 18-inch pipes are to be laid on a straight line under the drainage canal, and these are of sufficient capacity to carry the minimum flow of the sewer. When the amount of sewage so increases as to overcharge these two pipes, it will overflow into two 21-inch pipes laid as a siphon immediately under the 18-inch pipe, the flow through these 21-inch pipes ceasing as the amount of sewage approaches the minimum. Suitable arrangements are provided for flushing the 21-inch pipes, the 18-inch pipe being self-cleansing. Advantage is also taken of the opportunity of overflowing into the drainage canal in the event of an accident or stoppage in the main sewer, the 36-inch connection shown being designed to accomplish this purpose. Figs. 6, 7 and 8 show the various details of this crossing.

Figs. 9, 10 and 11, representing the crossing of the St. Bernard sewer under the Broad street canal, show the general plan which will be employed on all siphons. The sewer is divided into two sewers having the same capacity as itself. During ordinary flow, the sewage will run through one of these only until it runs full, when it overflows into the second sewer. The sewage is thus confined to a smaller channel, with beneficial results, during light flow, and with a relief in case either should become obstructed. Automatic flush tanks will give each sewer a thorough flush daily.

PUMPING STATIONS.

But little has been or can be said in connection with the pumping stations, as the plans are not sufficiently advanced to justify a full description of them at this time. It may be said briefly, however, that the complete plan calls for a total of three main pumping stations and thirteen small pumping or lift stations, of which the three main and six small pumping stations will be included in present construction. The greater number of the latter, however,

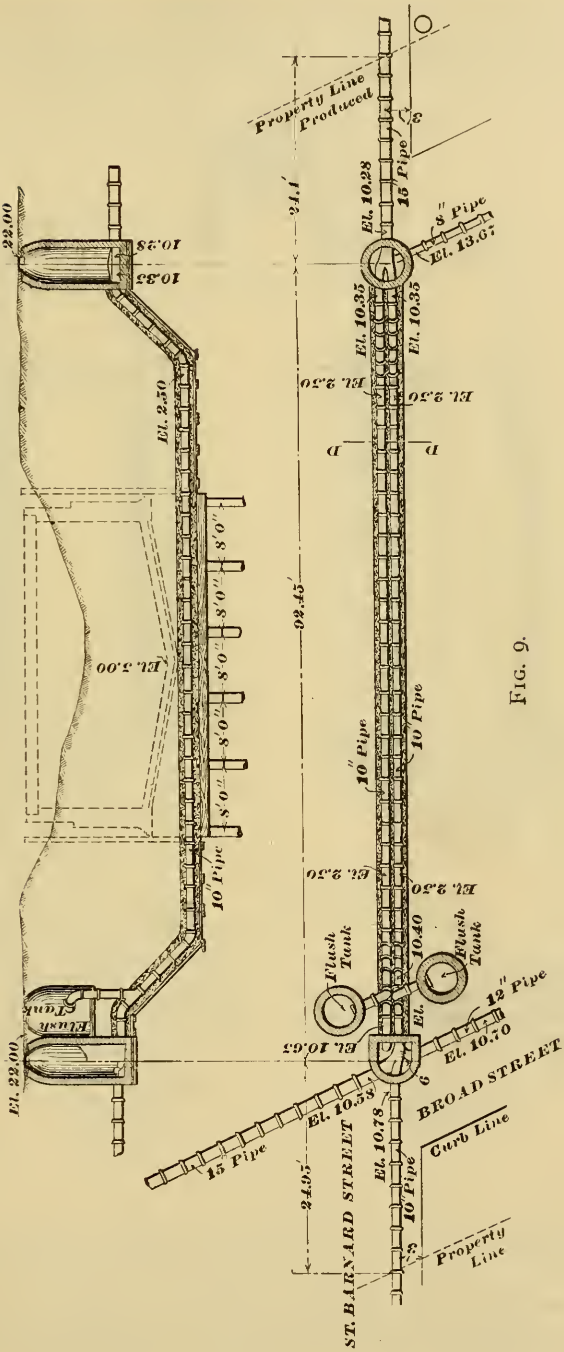

Property Line Produced
24.1'
15" Pipe
El. 10.28
8" Pipe
El. 13.67
10.28
10.35
22.00
El. 10.35
El. 10.35
El. 2.50
El. 2.50
El. 2.50
D
D
8'0"
8'0"
8'0"
8'0"
8'0"
El. 5.00
92.45'
10" Pipe
10" Pipe
10" Pipe
El. 2.50
El. 2.50
Flush Tank
Flush Tank
10.40
Flush Tank
El.
12" Pipe
El. 10.63
El. 10.70
El. 22.00
El. 10.58
BROAD STREET
15" Pipe
El. 10.78
Curb Line
24.95'
10" Pipe
ST. BARNARD STREET
Property Line

FIG. 9.

should hardly be dignified by the appellation of pumping stations, as the quantity handled there is very small, varying from 400 to 800 gallons per minute at present to an ultimate capacity of from 1000

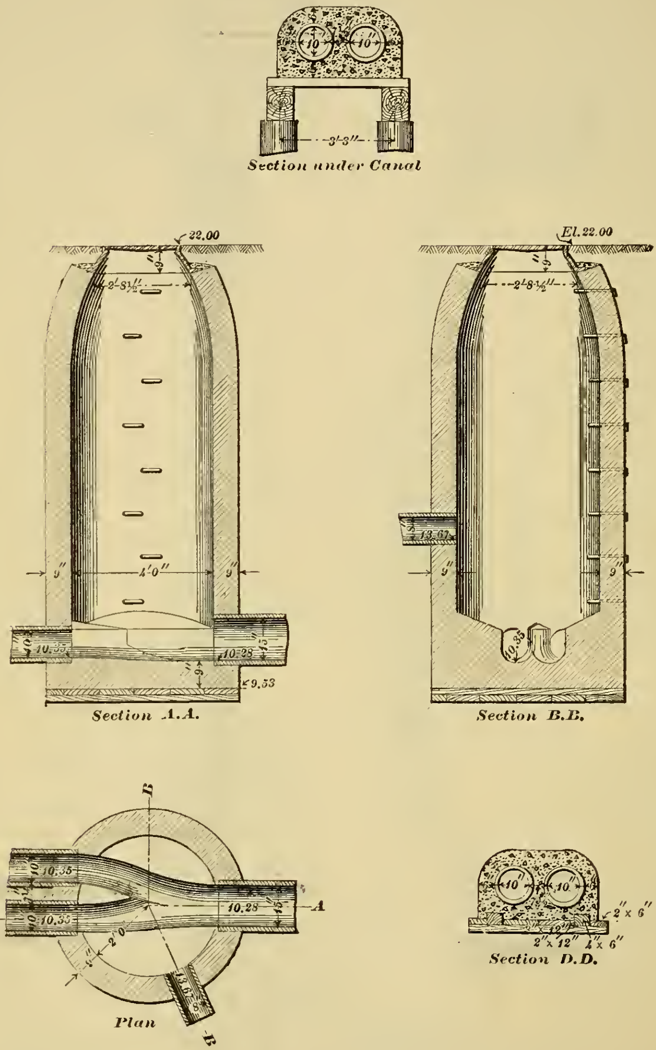


FIG. 10.

to 4500 gallons per minute. The pumps will be automatic in their action.

Of the three main pumping stations, one serves the whole of Algiers, ranging from a present capacity of 1500 gallons per minute to an ultimate discharge of 5000 gallons per minute. Another,

located at Jourdan avenue and Urquhart street, will serve all the territory between Lafayette avenue and the lower city line, the river and Florida walk with an estimated present capacity of 2500 gallons and an ultimate capacity of 13,000 gallons per minute. The third and main pumping station serves all the territory above

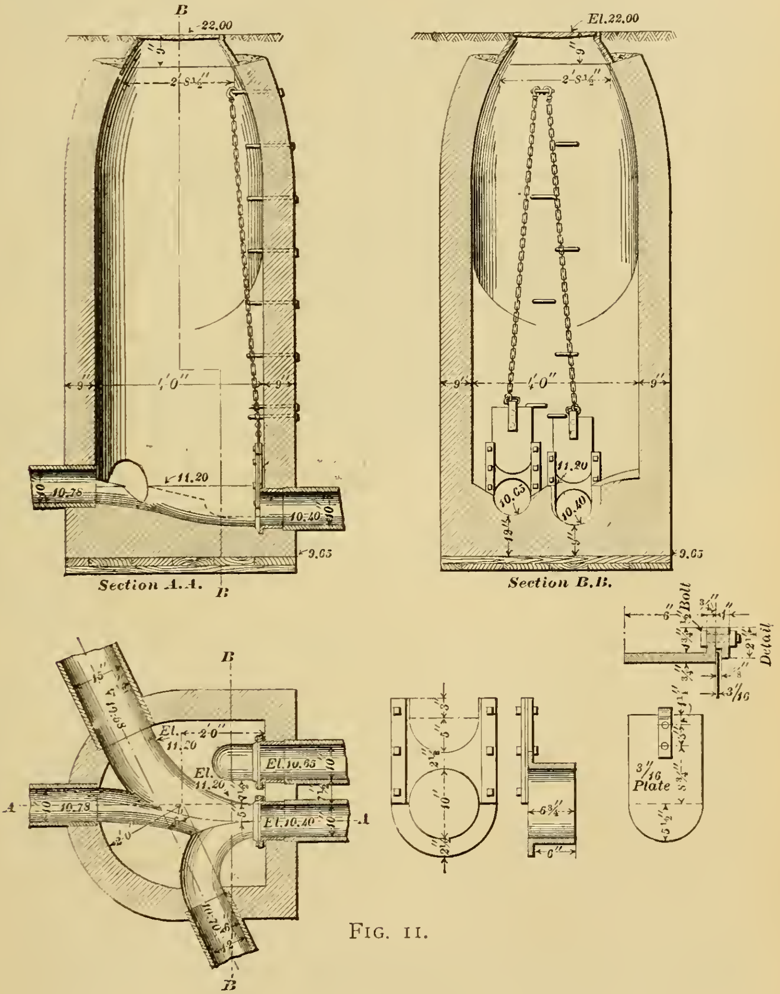


Fig. 11.

Lafayette avenue, designed for a present discharge of 26,000 gallons per minute, or 37,400,000 gallons in twenty-four hours, while it will be called upon ultimately to care for a flow of 57,200 gallons per minute, or 82,000,000 gallons in twenty-four hours.

It is hardly necessary to go further into a description of this design. While we have waited long for sewerage, the wait has not

been without some compensating advantages. When sewerage starts with the early life of a municipality, and the direction and extent of growth are undetermined factors, the engineer must depend upon his judgment to determine these, and yet is stopped from proportioning and designing his system for a period too far advanced, not only from financial considerations, but from inability to determine what the future demands may be. The result is necessarily more or less of a patchwork, requiring correction here, relief mains elsewhere, as the necessity arises.

Here, where the city has already grown to metropolitan proportions, and its future limits and conditions can be defined with almost mathematical accuracy, it has been possible to outline a system of sewerage as a completed whole, the most widely separated sections in perfect harmony and proportion to a completed structure; where the construction for present needs is in conformity with a well-defined and perfected plan, to be filled out and completed as the growing needs of the city demands. On the vast importance of this great work to the health of the community, recognized by all, it is useless to enlarge; we can only hope for its early consummation, when our city will have completed one great stride in the march of progress.

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SMOKE ABATEMENT IN ST. LOUIS.

BY WILLIAM H. BRYAN, MEMBER OF THE ENGINEERS' CLUB OF ST. LOUIS.

[Read before the Club, October 2, 1901.*]

OF all the cities of America burning soft coal, none feels the blight of the omnipresent smoke cloud more than does this city of St. Louis. It has made our name a by-word and a reproach. The comment of the Chinese minister was only the last straw needed to fix our degradation upon us. Now that we are in a fair way to realize our ambitions for good streets and pure, clear water, we venture to indulge the hope that the "new St. Louis" may be smokeless.

The problem of smoke abatement is an old one, and has often been discussed before this Club. I can hope, therefore, to give you but little if anything interesting or novel. In view, however, of the recent passage of a new smoke ordinance, and the more recent appointment of inspectors looking to its enforcement, it would seem that the time is propitious to briefly review the history of the movement in this city, to recapitulate the methods which have been successful and to indicate what we may reasonably hope to accomplish.

This discussion is limited to St. Louis, where the conditions surrounding the problem are as unfavorable as they could possibly be. Remedies effective here, therefore, may be accepted as equally so elsewhere.

St. Louis is naturally a smoky city. It is a busy city. Its industries cover a large volume and a wide variety of product. In no small degree does St. Louis owe its growth and its prosperity

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to its manufactures, and all good citizens are heartily in favor of encouraging them in every legitimate way.

St. Louis has come to be an important manufacturing center largely because of its proximity to the soft coal beds of Southern Illinois, scarcely a dozen miles to the east. These are apparently inexhaustible and are easily mined, making it possible to deliver this fuel to the consumer in St. Louis at exceedingly low cost. These coals leave much to be desired in many respects. They run high in volatile matter, moisture and ash, and comparatively low in calorific value, which characteristics, particularly the first-named, are highly favorable to the making of smoke when burned in the ordinary manner. It is the duty of the engineer to point out how the smoke nuisance may be abated while continuing the use of the fuel which Providence has sent us in such abundance. We must be prepared to meet the argument that a smoky city means a busy and a prosperous city, and to show that the prevention of smoke by modern methods imposes no hardships on our industries.

The Engineers' Club of St. Louis has long taken the lead in this movement. A review of its proceedings shows that many papers and discussions have been presented. We have long had a standing Committee on Smoke, which has at intervals made reports to the Club. These reports, it is true, have not always been as encouraging as might have been desired. There was not, in the early days, as thorough an understanding of the problem, nor had inventions been so far perfected as to give us the wide choice of remedy we have to-day. Nevertheless, there was always some progress to report.

There has always been a strong sentiment that the emission of smoke should be controlled by ordinance, but it was felt that, for the time being at least, our energies could best be directed toward the education of the public and the development of improved furnaces. In 1888 Mr. Charles E. Jones and Mr. Charles F. White—both pioneers in the movement in this city, and both then members of this Club, the former of whom is still with us—made a report to the president of the City Council which indicated that the forms of smoke-abating apparatus then available for steam boilers cut down their capacity an average of 28 per cent., and that their use involved a slightly increased expenditure of fuel. There were then, as now, a number of boiler plants which were regularly worked beyond their normal or rated capacities, and for them there seemed to be no satisfactory way of controlling the smoke.

In the same year, 1888, Mr. Robert Moore read a paper before this Club on "Smoke Prevention," which was a most able presenta-

tion of the status of the art at that time. It was a complete *résumé* of the local situation, and will well repay study even at this day. It is interesting to note that the optimistic views then held by Mr. Moore were destined to be fully realized.

Substantial progress had been made in 1891, when Mayor Noonan appointed a committee of citizens to investigate local conditions and to report upon the entire situation, with a view of pointing out what could be done toward the reduction of the smoke nuisance, complaint against which had become widespread and persistent. This committee, composed of Col. E. D. Meier, Prof. W. B. Potter, Mr. Robt. E. McMath and Mr. Charles E. Jones, all members of this Club, and familiar with the problem, at once accepted the task, and set systematically to work on the collection of data. On March 8, 1892, the committee made to a meeting of citizens, held at the Mercantile Club, a report which was studious and exhaustive, and which stands to-day as our highest authority. It is indeed the source and fount of wisdom for those who would study this problem thoroughly as it relates to St. Louis.

This report was shortly afterward repeated before this Club, and discussed at some length, after which it was published for general distribution. The committee recommended the passage of two ordinances by the Municipal Assembly, drafts of which were attached to the report. The first of these declared smoke to be a nuisance, and provided for its suppression. The other established an expert commission, which was to canvass the city and determine what could be done. This commission was also to make tests of smoke-preventing devices and smokeless fuels.

These ordinances were promptly introduced into the Municipal Assembly and were passed, and approved by the Mayor in February, 1893. President Burnet, of the Board of Public Improvements, with the approval of Mayor Noonan, appointed on this commission Prof. W. B. Potter, Capt. Wm. McClellan and the author.

At about that time the Citizens' Smoke Abatement Association was formed, with the object of educating public sentiment and of providing lawyers and inspectors to co-operate with the city officials. There were also appointed about this time two city inspectors, whose duty it was to report violations of the ordinance to the president of the Board of Public Improvements, who then took the necessary steps toward prosecution in the courts when that step seemed necessary.

This expert commission immediately entered upon its work, beginning with a canvass of the smoke-making plants, with a view

of determining the conditions, if any, under which smoke could not be entirely prevented, such conditions being a valid defense against complaint. It was also to report whether or not there were practical methods of abating the smoke.

These reports were duly submitted, together with a code of rules governing tests to be made on alleged smokeless furnaces. In due course exhaustive tests and reports were made on the Boileau furnace, the Hawley down-draft furnace, the Standard furnace or automatic stoker, the Keene Economizer and the Haxton base burner. All these reports were approved by the Board of Public Improvements and published. The commission also took up smokeless fuels, and made a series of trials and investigations upon coke, which report, however, has never been published. Another investigation into smokeless fuels of the character of Pocahontas was begun, but was not completed, owing to lack of funds.

During this time much other effective work was being done, both by the Citizens' Association and by the commission, the latter appearing before many bodies and meetings with a view of awakening a favorable sentiment. The members of the commission worked in close harmony with the Citizens' Association, and gave their advice free of charge to all inquirers looking for the best means of abating the smoke.

In the consideration of the smoke problem we should not forget the very excellent paper by Mr. R. J. McCarty, of Kansas City, Mo., read before this Club in December, 1895.

In the meantime the Citizens' Association and the city inspectors were pushing their part of the work actively, the most serious offenders being taken in hand to begin with. Both before and after the expiration of the six months period before the ordinance went into effect the owners of smoke-making plants took up the question of abating the smoke, and large numbers of them put in effective appliances. The willingness and desire to comply with the ordinance were almost universal. Every effort was made to induce compliance by friendly means, and it was not until moral suasion had failed that prosecutions were undertaken in the courts.

As is always the case, however, there were a few obstructionists who fought the ordinance, with the result that the now famous Heitzberg case was carried to the Supreme Court of the State, where, in 1896, very much to our surprise, the ordinance was declared invalid on the ground that the municipal legislature had exceeded its authority in declaring smoke a nuisance *per se*. This made it necessary to prove in each case that the particular smoke complained of had caused special and individual damage. This

decision, while not in harmony with the views of many eminent legal authorities, as well as the decisions of many high courts, was nevertheless conclusive, and ended our efforts under the ordinance. In the revision of the municipal code in 1899 the smoke ordinance was rewritten to conform to the Supreme Court decision, but nothing has been done under it on account of the practical impossibility of proving damage in each case.

In spite, however, of the many difficulties encountered, and the final overthrow of the ordinance, great good had been accomplished. Disinterested and competent outside observers said that St. Louis had done more than any other city in this country, and that our smoke cloud had been reduced fully 75 per cent. The city records show also that at that time about 75 per cent. of the steam boilers in this city had been equipped with smoke-preventing devices. Many of these have been kept in operation, so that our condition is not so bad now as it was before the original ordinance went into effect, although there has, of course, been some increase in the number of plants. Is it not reasonable to expect that even better results may be secured under the new ordinance?

Early this year the Executive Committee of the Citizens' Smoke Abatement Association, in conference with many leading citizens, prepared the draft of an act, to be introduced into the State Legislature, giving to cities of over 100,000 inhabitants the right to declare smoke a nuisance and to provide for its regulation. Such a law was duly passed and approved. (See appendix A.) In accordance with its provisions the Municipal Assembly of this city has passed a new ordinance, which was approved by the Mayor on August 21 last. (Appendix B.) He has now appointed a chief inspector and four deputies to enforce the ordinance.

Having now brought the situation up to date, let us get an exact idea, if possible, as to what smoke is.

The constituents of all fuels may be classified as volatile matter, fixed carbon and ash. The ash is inert as regards smoke, except that when present in large quantities it greatly impedes the proper handling of the fires. The fixed carbon, with which we are familiar in the form of coke, is smokeless. The remaining constituent, the volatile matter, occurs in large percentages in our fuels, and is the one which causes the smoke.

When a fuel rich in volatile matter is charged into a furnace, the result is that the volatile matter is first set free as a gas, principally in the shape of hydrocarbons. Part of these are of what is known as the olefiant series. These are dissociated at a red heat, and part of the carbon is set free, which, if unconsumed,

passes off, forming the visible smoke. It is possible to burn this free carbon, but to do so there must be sufficient oxygen present and the temperature must be high. Failing of either of these conditions, the furnace will smoke. All successful smoke-abating devices work in the direction of meeting these two important requirements.

It was shown long ago, by careful experiments, that the amount of carbon in the densest smoke is very small,—from one-sixth to one-half of 1 per cent. by weight. It has, however, an immense coloring power. You may, therefore, stamp as false all those claims of furnaces which offer to save fuel by consuming the smoke. It has, however, been shown repeatedly that the best forms of smokeless furnaces have made marked savings in fuel, not because they burn the smoke, but because of the improved construction and better engineering details, which bring about more favorable furnace conditions and result in more nearly perfect combustion. The best furnaces make a fuel saving more than sufficient to pay the interest on their cost, as well as repairs and maintenance.

Broadly speaking, there are three methods for stopping the smoke: First, the shutting down of smoke-making plants; second, the use of smokeless fuels; third, the burning of our ordinary fuels smokelessly.

Heroic as it may seem, much good has already been accomplished by the actual shutting down of plants. A few years ago the city was dotted with small factories, each with its smoke-making boiler. To-day most of these are operated by electric motors, supplied from central stations located at a distance and provided with smoke-preventing apparatus. Many buildings get their entire service of light and power from the street mains, operating their boilers only for heating during the cold months. This practice may be expected to grow as electricity becomes cheaper and is distributed over wider areas. It does not take the eye of a prophet to look into the not distant future when our generating plants will be located across the river, or at the coal mines themselves.

Much has been done in smokeless fuels, and they are already in extensive use in this city, particularly for heating, in the residence districts and for many special operations. Indeed, it is not too much to ask of the average good citizen that he will go to some little extra expense if necessary to aid in beautifying the city. This, however, could not be expected under steam boilers, which are our largest smoke producers. I had hoped that the oil from the newly opened Texas fields could be introduced here at something like reasonable cost, but present rates appear to be prohibitive.

Oil has many advantages, however, which would warrant some increase in cost over coal. In addition to solving the smoke problem it greatly reduces the labor charge, can be handled and controlled much more easily and usually permits an increase in the working capacity of the plant. On the other hand, however, the elements of danger and of odor should not be overlooked.

As indicating in a general way what may be done under boilers with the various fuels coming to this market I have prepared the following table. No claim is made for the absolute accuracy of the figures, but they are believed to be fairly reliable, relatively at least. A glance is sufficient to show that the smokeless fuels are out of reach in cost, except as the use of powdered coal may be developed.

FUEL.	Cost, Dollars.	Calorific Value. Heat Units.	Efficiency, per Cent.	Equivalent Evaporation in Lbs. of Water.	Cost of Evaporating 1000 Lbs. of Water.
	Per 1000 Cubic Feet.	Per 1000 Cubic Feet.		Per 1000 Cubic Feet.	Cents.
Fuel Gas	0.10	240,000	80	198.8	50.30
	Per Ton of 2000 Lbs.	Per Lb.		Per Lb.	
Anthracite	6.75	14,000	75	10.87	31.08
Texas Oil	8.08	15,950	80	13 22	30.56
Coke	4.50	12,500	70	9.05	24 87
Pocahontas	4.75	13,300	72	9.90	24 00
Big Muddy	2.50	12,200	68	8.57	14.60
Mt. Olive, Lump	1.60	11,200	65	7.53	10.62
Powdered Coal	1.25	10,000	80	8.28	7.55
Common Slack	0.90	10,000	60	6 20	7 25

The deliveries in this table are assumed to be on cars at consumer's switch. The oil weighs 7.43 pounds per gallon, and costs 3 cents per gallon, $2\frac{1}{2}$ cents of which is freight.

The oil companies hope to reduce the price in the near future to $1 per barrel of 42 gallons, but even at that figure it would still fall short of competing with coal in the St. Louis market, even after an addition of 40 to 50 cents per ton for coal and ash handling is made.

The outlook for oil is much better if, instead of burning it under boilers, it be used in oil engines of the Diesel or other modern type, which consume about $\frac{3}{4}$ pound of oil per I. H. P. hour, at a cost of 0.30 of a cent. The ordinary Corliss engine uses about 4 pounds of Mount Olive coal per I. H. P. hour, costing 0.32 of a cent.

In the table above it is assumed that the powdered coal is made from ordinary slack, at an additional cost of 35 cents per ton for powdering. As a matter of fact, this charge would be offset by the saving in labor for coal and ash handling.

After all, however, our greatest hope for immediate relief must come from the successful burning of our ordinary fuels smokelessly. As the largest offenders are the steam boilers, they only will be discussed.

Devices without number have been invented for this purpose, but, unfortunately, most of them have failed to meet the exacting requirements of regular service. These failures have led some good citizens, who have spent money fruitlessly, to believe that the problem is beyond solution.

It should be remembered that the ordinary furnace, without a special device, can be so handled as to greatly reduce the smoke, providing, of course, it is not overworked. It is not absolutely necessary, therefore, to buy a patent furnace in order to control the smoke, nor, as will be shown later, will the purchase of improved apparatus of itself control the smoke or insure the owner against prosecution. A deep furnace, high bridge wall, ample grate surface and good draft are essential to a good smoke record. Such a furnace, if skillfully fired, will make no serious smoke when working up to, say, two-thirds of its rated capacity. By skillful firing is meant the charging of alternate doors with small and uniform quantities of fuel, particularly if the coking system of firing is used. The firing of consecutive doors, at long intervals, with large quantities of fuel and by the sprinkling method is responsible for a very large proportion of the present smoke nuisance.

If the furnace, however, is not well designed, or is overworked, no amount of skill or care will keep the smoke within bounds. In such cases resort must be had to special apparatus. Successful devices and processes may be divided into five general classes:

First. Steam jets. These are the simplest devices in use, and they can be put together by any engineer at small expense. Sometimes they are placed under the grates, discharging into the ash pit, but more usually they are above the grate, immediately over the fire doors, or in the side walls, discharging backward or across and slightly downward. The steam jet draws in air and discharges it at high velocity immediately above the fuel, where it meets the gases being given off by the disintegrating fuel.

Devices of this character have come into extensive use. They are reasonably effective in reducing smoke, but are not usually economical in fuel. The jets are often allowed to blow continuously, but it is better to turn them on at the time of firing and then shut them off in two or three minutes, after the fresh fuel has become ignited. In some devices this is done automatically, the act of opening the fire door turning on the jet, and clockwork or

dash-pot mechanism gradually closing it. The objections to such devices are their first cost, their complicated character and the necessity for some attention and adjustment for fluctuating service.

In Fig. 1 is shown a simple device of this type, using air preheated in ducts in the side and end walls of the furnace.

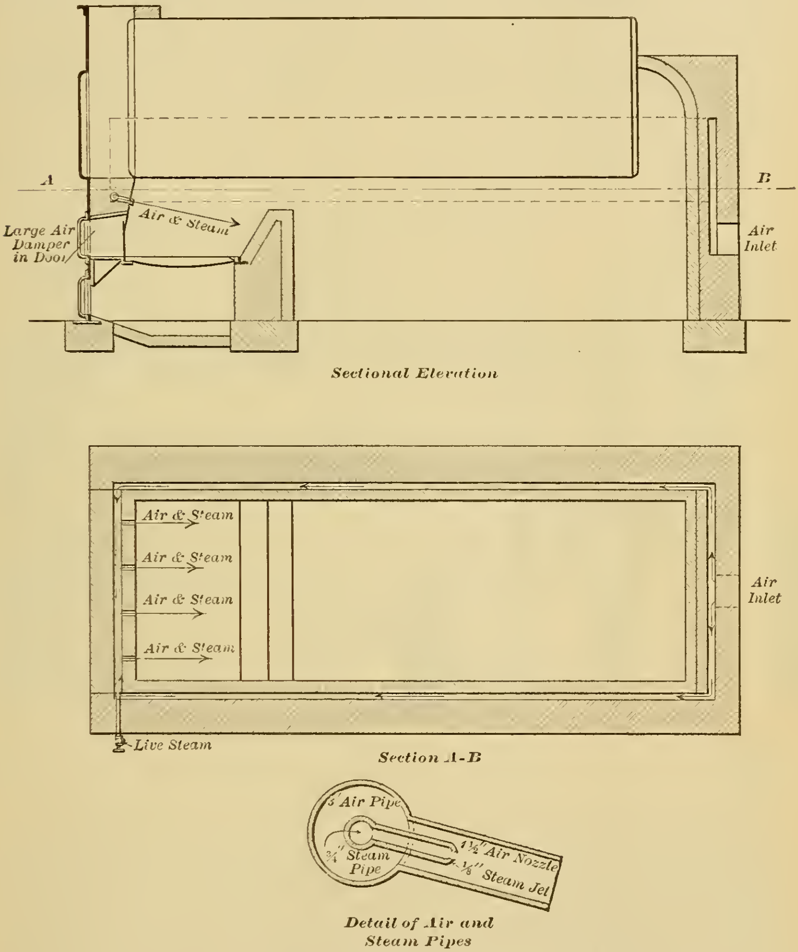


FIG. 1. STEAM JET DEVICE USING PREHEATED AIR.

Second. Cooking furnaces or firebrick arches. These come next in first cost, and are capable of giving almost perfect results in smoke abatement if properly designed and intelligently operated. The firebox is kept well away from the cooling effect of the heating surface, and can therefore be maintained at high temperature. Contracted checker work, or throat areas, insure a thorough mixture of air, which is often preheated. These are built in many

forms, many of which are capable of burning very inferior fuels. They are excellently adapted to plants where the service is reasonably uniform. The objections are that some forms require an increase of space, and the brickwork, if not properly constructed, may not be durable and repairs may be large. These objections, however, have been very largely remedied in the best types. There will usually be a material saving of fuel over the common setting if properly constructed and operated. Figs. 2 and 3 show successful forms of this type, the former representing the Reynolds and the latter the Kent furnace.

Third. Down-draft furnaces. These have proved very successful in many instances, and they have come into extensive use,

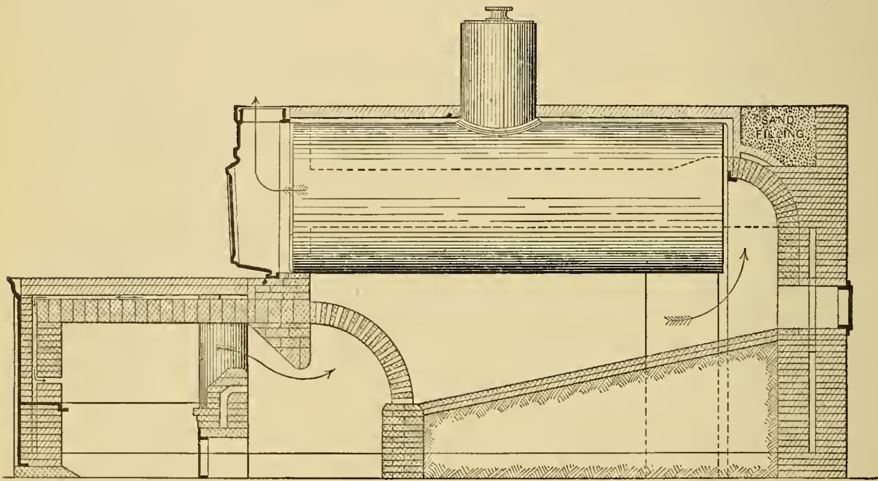


FIG. 2. FIREBRICK ARCH.

particularly where excessive demands for overwork are frequently made.

In the Hawley, one of the best-known forms (Fig. 4), there are two grates, one above the other. The upper grate is a row of water tubes, single or staggered, so connected as to form a part of the circulation system of the boiler. Grates of the ordinary pattern would not withstand the high temperatures. The tubes are inclined upward to the rear to insure rapid circulation. The space above the rear drum is closed off, and the gases must make their exit downward through the bed of fuel. Considerable partly burned fuel falls to the lower grate, where its combustion is completed under very favorable conditions. The two flames unite at the rear of the grates, forming a throat through which it is almost impossible for the particles of free carbon to pass unconsumed. Somewhat greater draft is usually required for this furnace than

for the common setting. Most of the air required for combustion enters through the doors above the upper grate only, a small amount being admitted under the lower grate. This furnace is independent of the skill or ignorance of the fireman to a greater degree than many others. The objections are its first cost and the fact that it is a part of the pressure system of the boiler. With bad water or careless or inefficient handling, there is great liability to tube and drum repairs. It usually effects a considerable saving in fuel.

Fourth. Automatic stokers, with which may be classed under-feed devices and chain grates. These have come into extensive

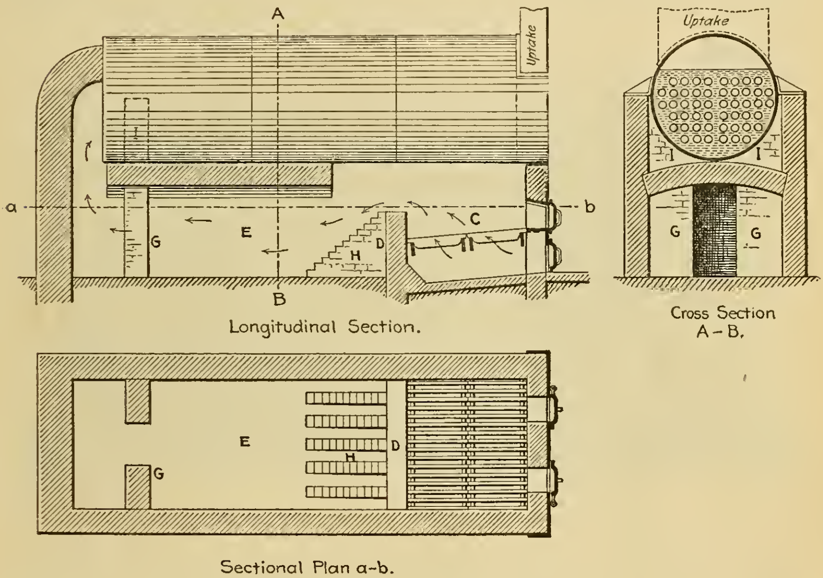


FIG. 3. WING WALL FURNACE.

use, particularly in large modern plants. While they are built in many forms, they all operate on the same principle,—that of feeding the coal automatically to the grates in continuous and regular amounts. Most of them are designed for the use of the finer grades of coal, such as nut, pea or slack. In many localities there is a surplus of this fuel, and its cost is low, but the increasing demand is raising the price and reducing the supply. Many recent stoker plants are provided with crushers to permit the use of the larger sizes of coal when necessary. When accompanied by coal handling and storage plants, the automatic stoker reduces the labor required in the fireroom, and this arrangement has been adopted in many large modern plants. The ability of the stoker to maintain practically uniform steam pressure and the fact that the air supply

is nearer the theoretical requirements are features which have contributed largely to its success.

The objections to automatic stokers are: First, their cost; second, the complication of parts and the necessity of repairs; third, the steam required to operate them. Under proper conditions there is a material saving both in fuel and labor. That the objections named are not serious is shown by the fact that their use is constantly increasing. The fuel to be burned should have expert study, however, before a device of this kind is selected, as they are not equally well adapted to all fuels. Some do not respond to fluctuating loads and to overwork as well as other types of furnaces.

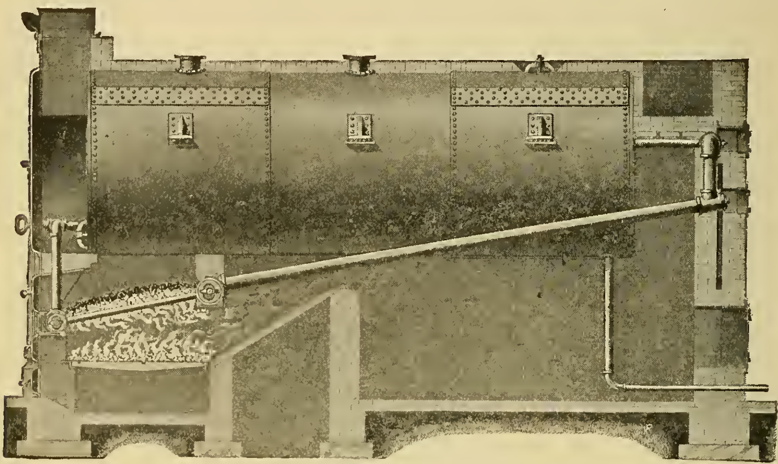


FIG. 4. HAWLEY DOWN-DRAFT FURNACE.

Well-known and successful forms of stokers are shown in Figs. 5 and 6; the former represents the Roney stoker, and the latter the Green traveling link or chain grate.

Fifth. Powdered fuels. These have recently attracted much attention, having been employed successfully in rotary cement kilns, and more recently under boilers to a limited extent. Experiments along this line have been going on for some time in European countries with considerable success. In the most satisfactory devices the coal is reduced to an almost impalpable powder, and is then forced into the furnace under pressure, exactly as would be done with oil or gas. Among the greatest advantages of this fuel is the fact that it may be made of slack or mine waste, which can be had at very low cost. While the apparatus for burning the fuel is simple and inexpensive, the plant necessary for preparing the fuel is somewhat elaborate. As the fuel is liable to spontaneous combustion, it cannot be stored or handled in large quantities, but

should be used as fast as made. This would seem to call for a powdering plant at each point of use. I am of the opinion, nevertheless, that good results may be looked for in this direction in the not distant future.

Time will not permit a discussion of all the methods which have been proposed, but the foregoing covers in a general way the devices which have been more or less successful. The list would not be complete, however, without mentioning double-combustion furnaces, smoke-washing apparatus, complete combustion devices, mechanical draft, etc. Some of these have come into limited use with encouraging results, both alone and in combination with others of the above-named types.

The classes enumerated above are not always clear and distinct, as the types named are often found in combination. The fire-

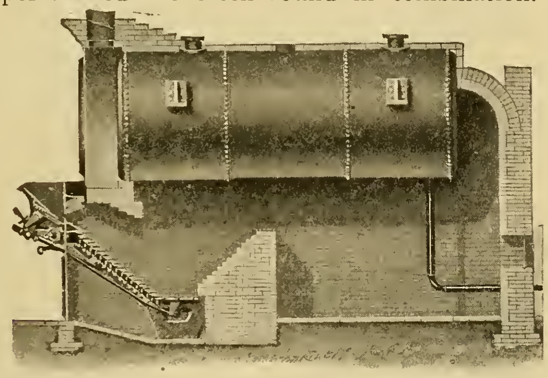


Fig. 5. Roney Stoker.

brick arch, for instance, is nearly always found in combination with the stoker, and often with the steam jet.

The fireboxes of locomotives and of steamboats require special treatment, but brick arches or steam and air jets have given good results. The best work is done when the two are combined. The arrangement is, of course, not economical in fuel, although it is not particularly wasteful. Some experiments have also been made with down-draft furnaces, with promise of success. Oil is admirably adapted for locomotives, and is already in extensive use where the cost will permit. It is urgently recommended that larger grate and heating surfaces be provided wherever possible.

I am unhesitatingly of the opinion that some one or more of these devices is applicable to every smoke-making boiler in St. Louis, and that, too, without hardship. The greatest care, however, must be exercised, first, in selecting the apparatus to be sure that it is adapted to the service; second, in seeing that it is care-

fully applied so as to be reliable and durable, and, third, that it is intelligently operated and maintained. The last is perhaps the most important of the three. No apparatus, however efficient, can be expected to run itself. Give it a chance; see that it is taken care of and kept in repair, and not abused.

It is to be hoped that the city of St. Louis will itself set a good example in this matter. Under the old ordinance work was handicapped by the fact that the water works plants, public build-

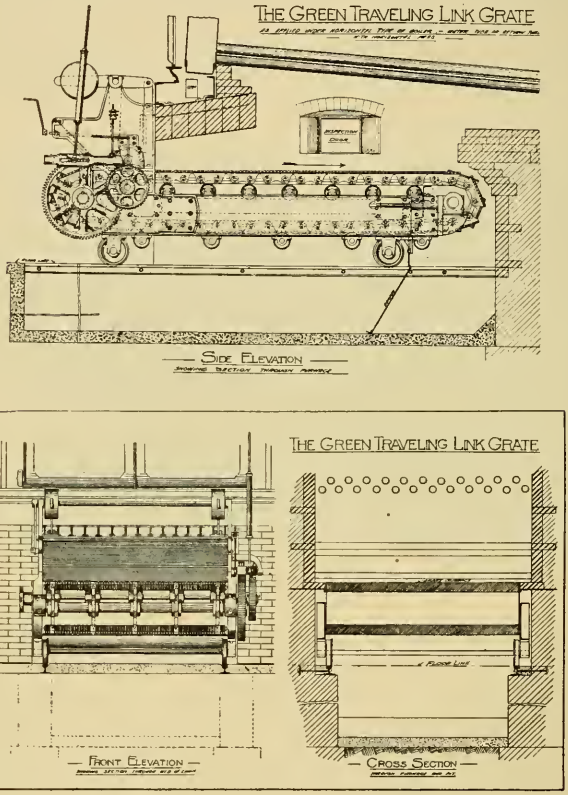


FIG. 6. THE GREEN TRAVELING LINK OR CHAIN GRATE.

ings and schoolhouses were very slow in stopping their smoke. It was hard to answer the argument offered in defense that the city itself was one of the greatest offenders.

I am in hopes that the World's Fair authorities will handle this problem in an effective manner. What could be more interesting and valuable than to show an immense power plant developing thousands upon thousands of horse power burning our own smoky fuels with perfectly clear stacks?

We can do this successfully, and with a wide choice of apparatus. In so doing we would give an object lesson to the world.

APPENDIX A.

An act to prohibit the discharge into the open air of dense smoke within the corporate limits of cities which now have or may have hereafter a population of one hundred thousand inhabitants; to declare the discharge into the open air of dense smoke within the corporate limits of such cities a public nuisance, and to provide penalties for the violation and enforcement hereof.

Be it enacted by the General Assembly of the State of Missouri, as follows:

SECTION 1. The emission or discharge into the open air of dense smoke within the corporate limits of cities of this State which now have or may hereafter have a population of one hundred thousand inhabitants is hereby declared to be a public nuisance. The owners, lessees, occupants, managers or agents of any building, establishment or premises from which dense smoke is so emitted or discharged shall be deemed guilty of a misdemeanor, and upon conviction thereof, in any court of competent jurisdiction, shall pay a fine of not less than twenty-five dollars nor more than one hundred dollars. And each and every day whereon such smoke shall be emitted or discharged shall constitute a separate offense; *Provided, however,* that in any suit or proceeding under this act, it shall be a good defense if the person charged with a violation thereof shall show to the satisfaction of the jury or court trying the facts that there is no known practicable device, appliance, means or method by application of which to his building, establishment or premises the emission or discharge of the dense smoke complained of in that proceeding could have been prevented.

SEC. 2. All cities to which the provisions of this act are applicable are hereby empowered to enact all necessary or desirable ordinances not inconsistent with the provisions herein, nor the constitution, nor any general law of this State, in order to carry out the provisions of this act.

SEC. 3. All acts or parts of acts inconsistent with this act, or any part hereof, are hereby repealed.

Approved March 21, 1901.

APPENDIX B—ORDINANCE NO. 20,455.

An ordinance to prohibit the discharge into the open air of dense smoke within the corporate limits of the city; to declare the discharge into the open air of dense smoke within the corporate limits of the city a public nuisance; to provide penalties for the violation and enforcement hereof; to create the positions of Chief Smoke Inspector, and Deputy Smoke Inspectors, prescribe their duties and salaries and the manner in which their work shall be controlled and supervised; and to repeal Sections One Thousand Five Hundred and One, One Thousand Five Hundred and Two, One Thousand Five Hundred and Three and One Thousand Five Hundred and Four of "The Municipal Code of St. Louis" (said sections being Ordinance Number Nineteen Thousand Seven Hundred and Seventy-two, approved April sixth, Eighteen Hundred and Ninety-nine).

Be it ordained by the Municipal Assembly of the City of St. Louis, as follows, to wit:

SECTION 1. Sections One Thousand Five Hundred and One, One Thousand Five Hundred and Two, One Thousand Five Hundred and Three and

One Thousand Five Hundred and Four of "The Municipal Code of St. Louis" (said sections being Ordinance Number Nineteen Thousand Seven Hundred and Seventy-two, approved April sixth, Eighteen Hundred and Ninety-nine) are hereby repealed, and they are hereby enacted in lieu thereof the following new sections:

SEC. 1501. The emission or discharge into the open air of dense smoke within the corporate limits of the city of St. Louis is hereby declared to be a public nuisance. The owners, lessees, occupants, managers or agents of any building, establishment or premises from which dense smoke is so emitted or discharged shall be deemed guilty of a misdemeanor, and, upon conviction thereof, in any court of competent jurisdiction, shall pay a fine of not less than twenty-five dollars nor more than one hundred dollars. And each and every day whereon such smoke shall be emitted or discharged shall constitute a separate offense; *Provided, however,* that in any suit or proceeding under this ordinance, it shall be a good defense if the person charged with the violation thereof shall show to the satisfaction of the jury or court trying the facts that there is no known practicable device, appliance, means or method by application of which to his building, establishment or premises, the emission or discharge of the dense smoke complained of in that proceeding could have been prevented.

SEC. 1502. The Mayor is hereby authorized to appoint a Chief Smoke Inspector and such Deputy Smoke Inspectors, not to exceed five in number, as may be, in his judgment, necessary to aid in carrying out the provisions hereof, and the provisions of the Act of the General Assembly of the State of Missouri relating to smoke abatement in cities of one hundred thousand inhabitants, approved March 21, 1901, and all such appointments shall be confirmed by the Council.

SEC. 1503. Said Chief Smoke Inspector and Deputy Smoke Inspectors shall hold their respective positions during the pleasure of the Mayor.

SEC. 1504. For all services contemplated by the provisions hereof the Chief Smoke Inspector shall receive from the city compensation at the rate of one hundred and twenty-five dollars per month, and each of said Deputy Smoke Inspectors shall receive compensation at the rate of eighty-three and one-third dollars per month, all payable monthly at the expiration of each month.

SEC. 1504 A. Said Chief Smoke Inspector and said Deputy Smoke Inspectors are hereby authorized, in the performance of their duties, to enter, at all reasonable hours, upon and into any and all buildings, establishments, premises and inclosures, in or from which they may believe that this ordinance, or the said Act of the General Assembly of Missouri, has been or is being violated; and to inspect and examine such building, establishment, premises or inclosure in order to ascertain whether or not there is any known practicable device, appliance, means or method by the application of which to said building, establishment or premises the emission or discharge of dense smoke therefrom into the open air could have been or can be prevented. Said Chief and Deputy Smoke Inspectors shall collect and preserve evidence of all facts touching violations of this ordinance, or of said Act of the General Assembly, and said Deputy Smoke Inspectors shall make reports of their examination and investigation to the Chief Smoke Inspector at such times and in such manner as he may direct. Said Chief Smoke Inspector shall report all cases of violation of this ordinance to the proper officers, or

prosecuting officer, for the prosecution of the offenders, and he and said deputies shall aid in all such prosecutions by furnishing whatever evidence they may have procured. They shall devote on each day to the discharge of their duties at least the number of hours provided by Section 11 of Article IV, of the City Charter, and for failure to do so, or for any other reason satisfactory to the Mayor, they may be removed by him at any time. The Chief Smoke Inspector shall furnish the Mayor with reports and information whenever he shall be required to do so.

Sec. 1504 B. The appointments and the removals of Smoke Inspectors, under this ordinance shall be made matters of official record. Each Smoke Inspector when appointed shall be furnished with a certificate or written evidence of his appointment, signed by the Mayor, which certificate or written evidence such Smoke Inspector shall exhibit if required by any person upon whose premises he proposes to enter for purposes of inspection. All Smoke Inspectors shall be guided in the performance of their duties by such orders and directions as the Mayor may see fit from time to time to give them.

Sec. 1504 C. It is hereby made the duty of all patrolmen and officers of the police force of the city to assist said Smoke Inspectors in the performance of their duties, and to report to the Chief of Police all violations of this ordinance coming to their knowledge.

Sec. 1504 D. Any person who shall interfere with any of the Smoke Inspectors hereinbefore provided for, in the discharge of their duties, or shall hinder or prevent any of said inspectors from entering into or upon, or from inspecting any buildings, establishments, inclosures or premises in the discharge of their duties, shall be deemed guilty of a misdemeanor and on conviction thereof shall be subject to a fine of not less than twenty-five dollars nor more than one hundred dollars for each offense.

Approved August 21, 1901.

THE EFFICIENCY OF COMPOUND CENTRIFUGAL PUMPS.

By Prof. F. G. Hesse, Member of the Technical Society of the Pacific Coast.

[Read before the Society, November 1, 1901.*]

In 1869 I volunteered to design a centrifugal pump for the Stanislaus Water Company, of which Mr. N. W. Spaulding was president. It was a two-stage compound pump; that is, a combination of two pumps, exactly alike, having the shaft in common, arranged so that the first pump discharged into the other, and each provided with a free vortex for the purpose of converting into pressure the kinetic energy of the absolute velocity of discharge from the runners.

The important question now presented itself, How does the efficiency of such a combination of two or more pumps compare with that of a single pump doing the same duty?

The power lost in a centrifugal pump may be separated into three separate losses, viz:

1. Friction of shaft in bearings, independent of quantity discharged.

2. Friction of water as it passes through suction pipe along the vanes of runner into the discharge pipe, proportional to square of quantity discharged.

3. Friction of runner rotating in water, independent of quantity discharged.

Unfortunately, no tests heretofore made, so far as I know, have recognized the loss of power due to the wheel discs; that is (3), above, and in consequence those losses have been charged to the "hydraulic" resistance, thereby producing coefficients of resistance too large and otherwise giving rise to formulas which are misleading and standing in the way of a true interpretation of the phenomena presented by the action of the pump under different conditions and elements of construction. The theory of the centrifugal pump, as usually given, will not explain the experimentally demonstrated higher efficiency of a compound pump over a single pump, as will be shown later.

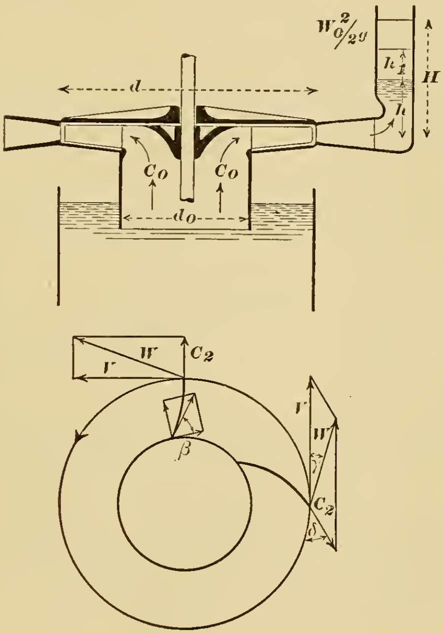
In 1869 no experiments on the friction loss of discs rotating in water had been made, as far as I could ascertain, and I was obliged to use a formula which I developed on a purely theoretical basis. Its application proved conclusively that the compounding

*Manuscript received December 5, 1901.—Secretary, Ass'n of Eng. Socs.

of pumps increased the efficiency over that of the single pump doing the same duty.

Much to my regret, the pump referred to was never built, owing to the dissolution of the Stanislaus Water Company, and the drawings, which had been kept at the company's office, disappeared. Mr. Spaulding informed me later that some one of the company had secured a patent, or caused a patent to be obtained by a manufacturing company in New Jersey.

Matters remained *in statu quo* until the year 1887, at which time I published University Bulletin No. 2, on a "Hydraulic Step,"



which contained the results of experiments on the resistance offered to discs rotating in water.

I found the energy lost in foot-pounds per second to be

$$W = 0.105 \lambda n^3 d^5 \qquad (1)$$

in which

n = number of revolutions per minute.

d = outer diameter of disc in feet.

λ = a coefficient.

This coefficient λ is a function of *d* and *n*. The variation of *n* is mainly felt for small velocities, and can be neglected, since the use of the formula deals with large values of *n*. λ, as a function of *d*, approaches an asymptote for *d* greater than unity.

Expressing W, the energy lost per second, in terms of the peripheral speed of the disc, we find

$$W = 0.00205\ d^2\ v^3 \tag{2}$$

which formula shall be applied to the theory of the centrifugal pump.

We shall use the following notation in connection with the diagram representing a pump with a diffuser:

d = diameter of runner in feet.
v = peripheral speed of runner.
Q = quantity of discharge in cubic feet per second.
h = height to which Q is to be raised.
$h_{\prime}$ = hydraulic head lost.
w_o = velocity of discharged water.
g = acceleration of gravity.
d_o = diameter of inlet pipe equal to inner diameter of runner.
$e = \frac{d}{do}$
σ = density of water in pounds per cubic foot.
c_o = velocity of water in inlet pipe.
$h_1 = \xi\ h$.
δ and γ = angles as shown in the figure.

Also since $Q = \frac{\pi\ d_o^2\ c_o}{4}$

it is $d^2 = \frac{4\ e^2\ Q}{\pi\ c_o}$

The total head against which the pump works is

$$H = h + h_1 + \frac{W_o^2}{2g} \tag{3}$$

in which $\frac{w_o^2}{2g}$ is the head corresponding to the velocity of discharge.

Accordingly the work per second is $H\ Q\ \sigma$.

The theory of the pump indicates that

$$v^2 = g\ H\left\{\frac{1 + \tan \gamma}{\tan \delta}\right\} = g\ H\ B \tag{4}$$

where B is a constant depending upon the construction of the pump.

The introduction of γ as a characteristic is due to Prof. G. Hermann, Technical University, Achen.

Equations (2) and (4) are sufficient to determine the formula for efficiency of any pump, simple or compound.

Expressing *d* in terms of Q, and substituting for v from (4), it is

$$W = .475\ \frac{e^2\ h^{\frac{3}{2}}\ (1 + \xi)^{\frac{3}{2}}\ B^{\frac{3}{2}}\ Q}{c_o} \tag{5}$$

neglecting $\frac{W_o^2}{2g}$ as very small compared with h and h_1 in any actual

case. The hydraulic efficiency $= \dfrac{\text{Useful work done}}{\text{Useful work done} + \text{hydraulic losses}}$

$$= \eta = \frac{Q\,\sigma\,h}{(1+\xi)\,h\,Q\,\sigma + .475\,\dfrac{Q\,e^2\,h^{\frac{3}{2}}}{c_o}\,(1+\xi)^{\frac{3}{2}}\,B^{\frac{3}{2}}} \tag{6}$$

and the efficiency with *m* pumps in series working under the same head *h* is

$$\eta = \frac{m\,Q\,\sigma}{m\,(1+\xi)\,\frac{h}{m}\,Q\,\sigma + .475\,m\,\dfrac{Q\,e^2\left(\frac{h}{m}\right)^{\frac{3}{2}}}{c_o}\,(1+\xi)^{\frac{3}{2}}\,B^{\frac{3}{2}}} \tag{7}$$

which, divided through by $Q\,\sigma\,h$, becomes

$$\eta = \frac{1}{1+\xi+.0075\,e^2\left(\frac{h}{m}\right)^{\frac{1}{2}}\dfrac{(1+\xi)^{\frac{3}{2}}\,B^{\frac{3}{2}}}{c_o}} \tag{8}$$

This is the final formula for the efficiency of a compound pump, and it indicates that, for a given head *h*, the efficiency will increase with the number of stages or pumps in series.

If we had assumed the disc friction loss proportional to the square of the velocity, with the same coefficients, the efficiency

$$\eta = \frac{1}{1+\xi+\dfrac{e^2\,B\,(1+\xi)}{c_o}\,.0075}$$

which formula will not account for the observed higher efficiency of a compound pump over a single pump doing the same work. This greater efficiency is due to the decrease of the disc friction loss by diminishing the peripheral speed of the runner, as indicated in the formula (7). It should be mentioned here that I have not yet had an opportunity to determine the coefficient ξ for different styles of runners and constructions, but the equipment of the new hydraulic laboratory at the University of California will render this possible in the very near future. In the following table, showing how a change in B of formula (4) and *m* affects the efficiency, I have taken $\xi = 0.3$:

ξ	e	h	m	$(1+\xi)^{\frac{3}{2}}$	c_o	δ	γ	$B^{\frac{3}{2}}$	v	η = hydraulic efficiency
0.3	4	900	1	1.48	4	15	25	4.57	320	.35
0.3	4	900	1	1.48	4	90	*	1.00	170	.62
0.3	4	900	9	1.48	4	15	25	4.57	107	.56
0.3	4	900	9	1.48	4	90	*	1.00	57	.71

* When $\delta = 90^\circ$, B becomes unity irrespective of the value of γ.

SUMMER STREET VIADUCT, SOUTH BOSTON.

By Herman K. Higgins, Member Boston Society of Civil Engineers.

[Read before the Society, June 19, 1901.*]

The Summer street viaduct, South Boston, is essentially a part of the general expansive movement, observable for a few years past, on the part of the business of Boston, using the term in the broad sense and including therein not only the buying and selling of goods, but as well the transportation, storage and shipment of much material that passes through Boston's railway terminals to foreign countries without involving any financial transactions in Boston proper.

As our city's importance as a commercial center increases, it becomes increasingly difficult to transport merchandise through crowded streets to wharves in the city proper, and the difficulty may be expected to increase even more rapidly in the future.

Within the past few years, owing partly to the inevitable consolidation of land transportation companies, but principally to the geographical peculiarities of our city, the condition has arisen that there is but one principal artery of travel between the railway terminals and the wharves of the city proper, that is, Atlantic avenue. Already, at certain times of day, the capacity of the street is severely taxed, and the increased local traffic, incident to the business which will doubtless be fostered by the improved means of transit provided by the elevated railway, has of course yet to be felt and should be liberally allowed for. It is not financially practicable to widen such a street, nor is it practicable to so administer it as to keep it always reasonably safe and clear of blockades.

It will be seen, therefore, that available dock frontage in localities more accessible, particularly from railway terminals, is a prime necessity if Boston is to continue to increase in commercial importance. Moreover, the older docks and wharves are already tolerably well occupied by traffic in lines which have been for some time in possession of certain territory, and could be removed only at considerable loss. For example, the fisheries near T wharf, various coal wharves and power plants, the excursion steamer lines, ferries, etc., all small items in themselves, but aggregating enough to occupy a very appreciable share of the available water frontage of the city proper. Under these conditions trade must naturally turn to districts more remote from the older center of business.

*Manuscript received December 20, 1901.—Figs. 1 to 4, inclusive, reprinted, by permission, from "Engineering Record" of December 21, 1901.—Secretary, Ass'n of Eng. Socs.

Another reason, not less important perhaps, is found in the fact that the older part of the water front is owned in comparatively small parcels by a considerable number of persons. This effectually prevents any large system of improved facilities such as other ports have found essential to their growth and continued prosperity.

Fortunately, the larger Boston is so situated that commercial expansion can be carried to an almost indefinite extent, and we find that for some time the bulk of the heavier traffic has taken itself to Charlestown, East Boston and South Boston.

Charlestown's docking facilities are comparatively well developed, and the new Charlestown Bridge on the one hand and the railway facilities offered by the Boston and Maine Railroad leave little to be desired in the way of transportation possibilities to assure the ultimate perfect utilization of its comparatively limited water frontage.

East Boston is unfortunately not so happily situated, as it is handicapped in handling local traffic by the natural barrier set by the harbor imposing the use of ferries to secure access to the business center of the city. Notwithstanding the excellent management and equipment of our ferries the limitations imposed by fog, weather and a crowded harbor form a condition which must have considerable effect upon any business requiring their use. Its rail connection, also, leaves much to be desired, as the many and dangerous grade crossings will ultimately have to be eliminated and the cost of so doing will constitute a charge upon traffic which, although not readily visible to casual observation, is nevertheless a real handicap to its future growth and prosperity. Its natural advantages, however, are so great that it has already a very large share of the trans-Atlantic trade of Boston, and its opportunities for expansion are nearly unlimited.

South Boston, unlike its two sister localities, has had so far comparatively little development, notwithstanding its natural advantages are of the best. Its rail approaches are direct, and have only one grade crossing, and that not very serious, as the bulk of its street traffic is heavy trucking, and its ultimate abolition should not prove exceptionally expensive. Its room for future growth is nearly as unlimited as East Boston, and long before its full development the business of ocean transportation may have undergone such transformations that all our docks may require complete reconstruction. The movement just begun of consolidation of steamer lines seems destined to effect great changes in a few years. Its means of access from the city proper have, however, been in the

past not so satisfactory, Congress street, the only direct thoroughfare, being narrow and crowded by local freight traffic to and from the railway yards. The State docks and future extensions will shortly call for largely increased facilities for access to the business center. The water frontage of South Boston proper must also sometime be included in the general harbor system, and a great and still growing population is clamorously demanding better means of access to the city.

To accommodate all these interests, a wide, commodious avenue across the South Boston Flats, as they were formerly called, became a necessity, and postponement of its construction could only result in a greatly increased cost, as the appreciation of values in this district is rapid and continuous.

A number of studies were made at various times with the object of determining whether a change in level of Congress street would not upon the whole best serve the interests of all concerned, as it is apparent that Congress street is very close to the most desirable location for such an avenue. Such studies seem to show conclusively that this would not finally solve the problem, and that the legitimate function of Congress street is to provide for the already large and growing warehouse business located between the railway and Summer street and the local freight service of the New York, New Haven and Hartford Railroad, leaving the new thoroughfare, Summer street, to form a means of access to the lands east of the railway terminal, including the State's docks, the shipbuilding interests, present and prospective, and whatever through traffic may in time be developed.

The planning of this street or viaduct was in itself something of an undertaking and would be more highly appreciated were it not for the dwarfing effect of the greater problems presented by the construction of the passenger terminal so nearly adjacent.

The effect of gradient on such a street, carrying as it must a very heavy traffic, is seen to be most serious, and heavy expenditure is warranted in the effort to reduce it to a minimum. The viaduct over the railway, on the contrary, calls for as much room as possible over the tracks, not only to reduce risk to brakemen, but of nearly equal importance to reduce the deterioration due to corrosion. This element of clear room over the stack of a locomotive is not yet properly appreciated, even by the engineering profession, and those who have occasion to maintain metal structures exposed to such conditions know that mere painting, even when frequent and accompanied by thorough cleaning, forms at best a very unsatisfactory means of protection. The life of iron over

locomotives varies according to the distance from the stack to the surface exposed, probably somewhere nearly as the square of said distance.

A viaduct over a railway freight terminal must also leave ample room for handling bulky machinery and other freight, and in this case it was needful to provide room enough to construct tight roofs over the freight houses, one of which had already been built and two others were under way.

The final determination of grades was therefore in the nature of a compromise and called for the exercise of considerable judgment to properly evaluate the conflicting interests.

The width of the street, 100 feet, is fixed by general local practice rather than by any formally logical process. There is, however, already sufficient occasion to believe that long before the complete development of the territory tributary to this street there will

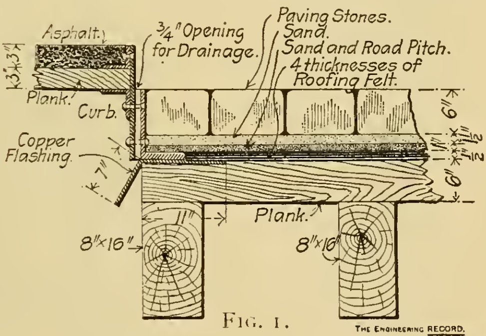


FIG. 1.

be no lack of crowding on even this 100-foot thoroughfare. It should be remembered in this connection that Atlantic avenue is essentially a distributing street; most of its traffic following it for only a few blocks, then turning up some of the radial streets toward the center of business, whereas Summer street will ultimately be more of a thoroughfare.

The character of the expected traffic on this street fixed the surface finish, it being early apparent that nothing short of granite block pavement would be at all permanently satisfactory. This materially increases the weight to be carried, but is of less importance than frequent blocking of traffic to permit repairs to a less durable pavement.

This pavement weighs about 120 pounds per square foot, with its pitch joints and sand cushion, and rests on a layer of waterproofing material consisting of about one inch of tarred sand on a four-ply layer of tar-paper, thoroughly mopped with hot tar, similar in general to an ordinary tar and gravel roof. (See Fig. 1.)

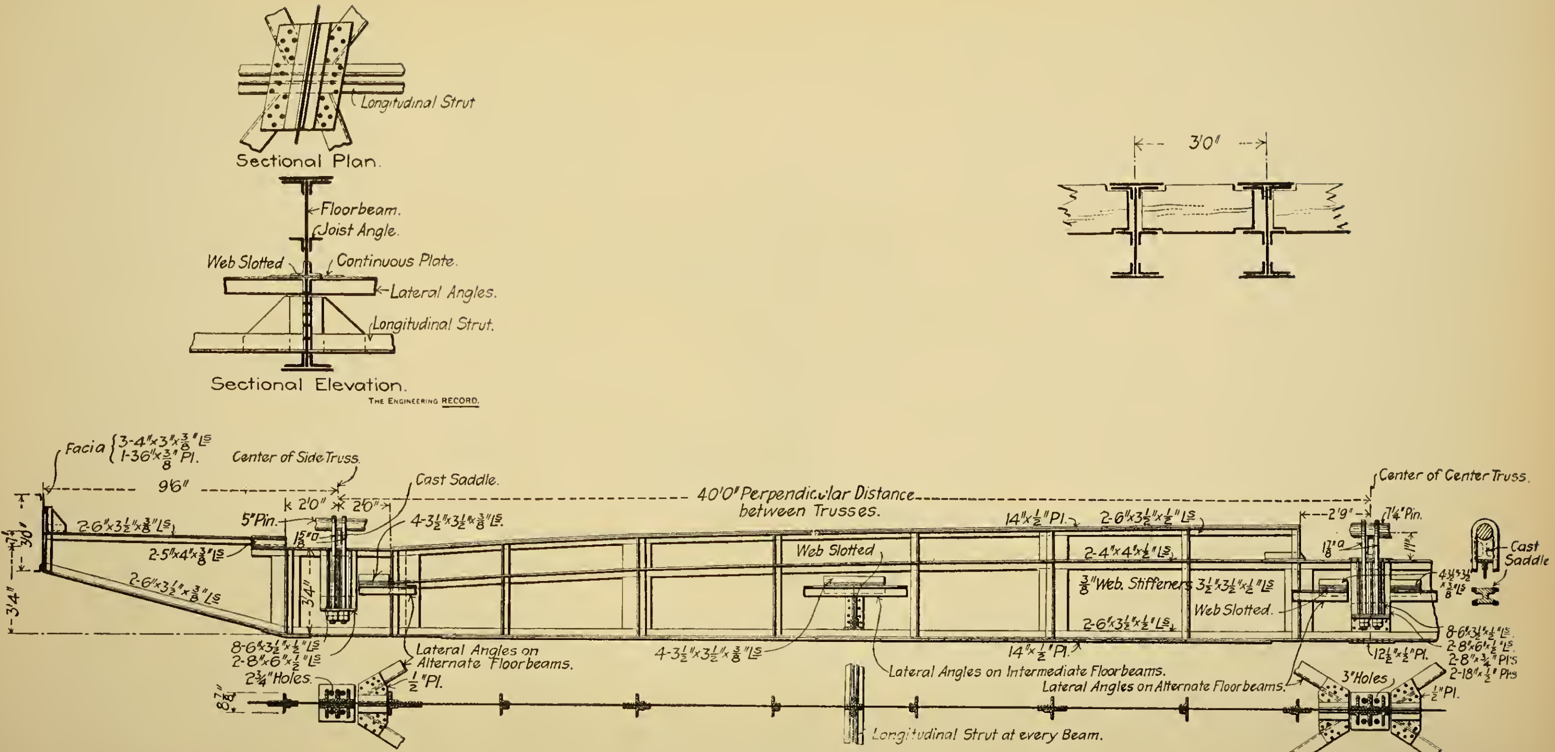


FIG. 2. TYPICAL FLOOR BEAM.

To safely carry this heavy pavement and the expected heavy live load, even after a considerable amount of decay, the driveways were planked with 6-inch hard pine and the sidewalks with 3-inch hard pine. Stringers were made 8″ x 16″ under the driveways and 3″ x 12″ under the sidewalks, and will safely carry a steam roller or a steam motor carriage of the European type, which will no doubt in a few years become as common here for heavy freighting as the electric cabs now are for passenger traffic.

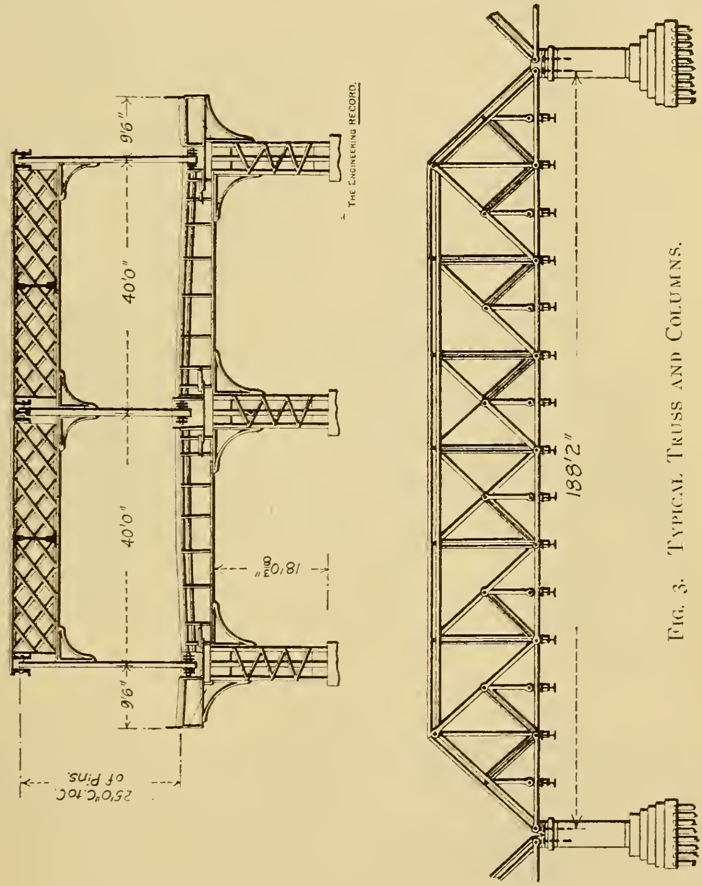


Fig. 3. Typical Truss and Columns.

As all this timber would in time decay and the interruption to traffic for repairs will in a few years become a serious matter, and as the rapidly progressing destruction of our forests will have materially increased the cost of lumber by the time such renewals will have to be made, it was determined to subject all the lumber to some preservative process, and the creosoting process, so-called, was selected as having the preponderance of evidence in its favor.

The wooden stringers rest on shelf angles on the steel floor beams, with their tops nearly flush with the floor beam flanges. This enables the use of a deep and stiff floor. (See Fig. 2.)

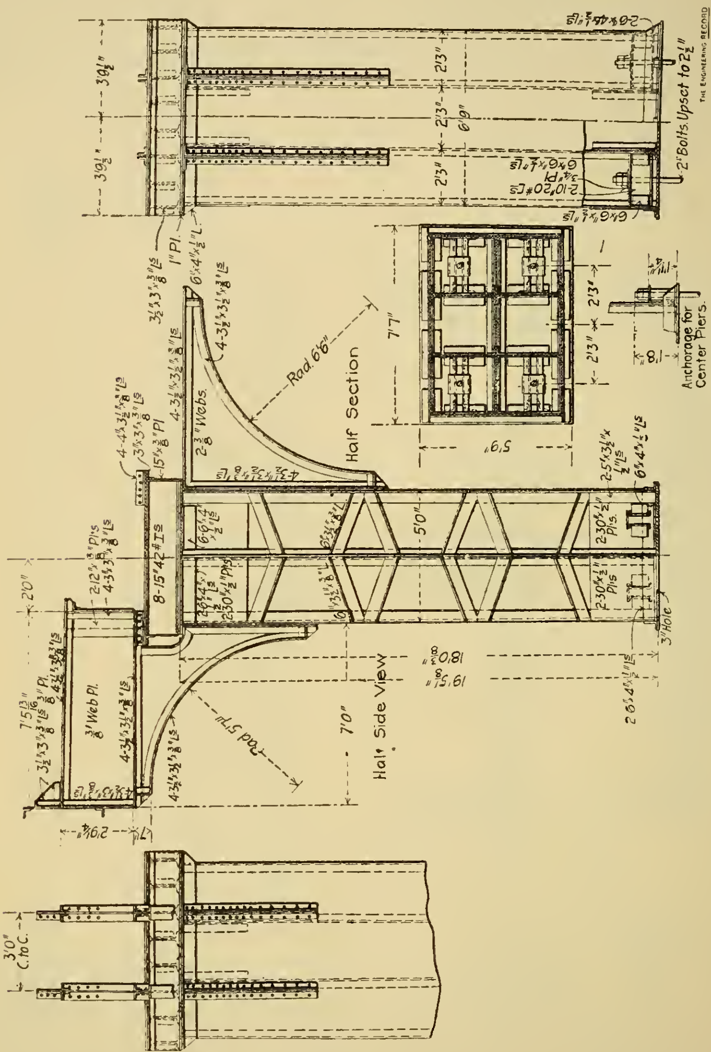


Fig. 4. Detail of Side Columns.

In order to reduce the span and consequent weight of the floor beams as much as practicable and also to keep the truss sections down to reasonable limits, three trusses were determined upon, spaced forty feet apart on centers. The sub-Pratt type was chosen as the most economical and generally satisfactory. They are notable only for their great weight. The trusses rest on steel seg-

mental rollers 12″ in diameter; these on steel columns, and the columns on the masonry piers. (See Fig. 3.)*

The use of steel columns in place of the more usual stone piers enables much room to be saved under the bridge, as the necessary spread of base can be carried below the floors of the freight houses. The columns are also more rigid against overturning, being anchored deep into the masonry, and cost, if anything, a little less than masonry piers. Their weight being much less, the foundation may be smaller, and the ultimate cost is materially reduced without any sacrifice of efficiency. (See Fig. 4.)

The lengths of spans were fixed by the necessity for reducing to a minimum the obstruction to the future development of the terminal below. To this end the piers were placed in the centers

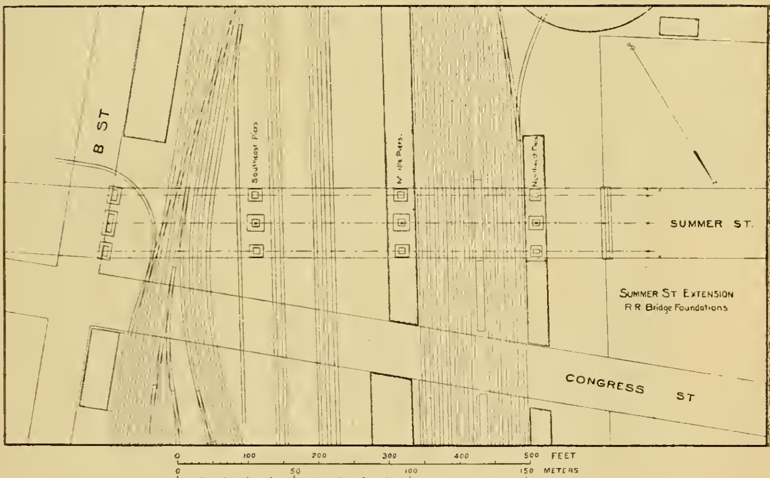


Fig. 5. Railroad Bridge Foundations.

of the freight houses to permit trucking freely between and around them and in the center of one of the driveways devoted to teaming bulk freight. (See Fig. 5.) The piers adjacent to B street, Fig. 6, were designed to form part of the wall of a future extension of the freight house to cover the entire B street frontage of the property, which will logically form a feature of its ultimate development. As doors will be needed, the space between truss bearings was left unencumbered by needless masonry.

The foundations of such a structure, while logically the final consideration, are constructively the first to be put under way, and

*For a more detailed description of superstructure see "Engineering Record" of December 21, 1901.

in this case are of the first importance. The geological formation is similar to much of the low-lying portion of Boston, being of clay covered with miscellaneous filling. Being made land, the clay was rather wet, and consequently soft. Piles were driven two feet apart on centers each way. The number of piles in each foundation was fixed by the load on the pier, which varied somewhat, and the piles were allowed to carry some twelve tons each. As the soil is certainly good for one ton per square foot, the actual load transmitted by the pile to the strata blow cannot much exceed eight tons.

This work offered a notable example of the consolidating effect of piles upon the adjacent soil. The first piles in each group drove easily, and the resistance increased with reasonable uniformity. As the group approached completion, however, the resistance increased markedly, and the last few piles were driven with

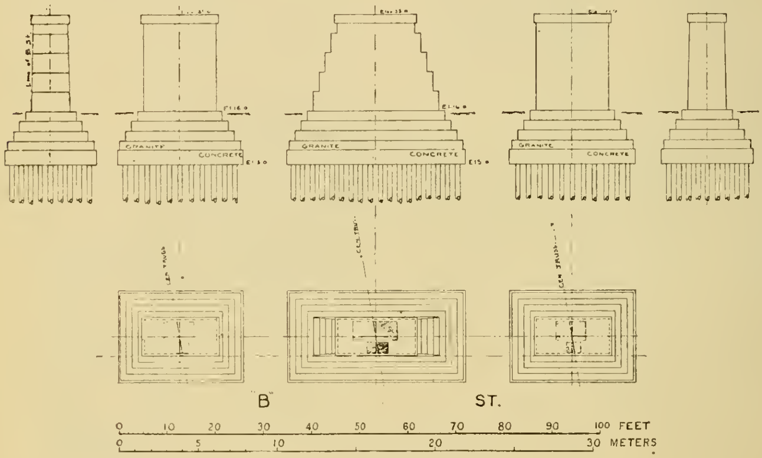


Fig. 6. B Street Piers.

considerable difficulty. The bottoms of the pits were forced up and the sides were forced in, and additional excavation was necessary to make room for the masonry.

The piles being driven and cut off, concrete was placed about their heads for a depth of one foot. The concrete was of Portland cement, sand and screened gravel, in the proportions of one, two and four, mixed unusually wet, and thoroughly compacted about the piles. This concrete extended two feet above the piles and formed the lower course of the masonry. On it was laid the body of the pier in two-foot courses of split granite of superior quality in rectangular blocks, very thoroughly bonded, each stone being shown on detail drawings of each course, with all dimensions and positions of joints specified.

These piers are designed to fully utilize the strength of the granite and spread out the foundations to the requisite extent as rapidly as possible, thus saving excavation and pumping. The ground water level in this vicinity is very close to the surface, and piles cut off at grade 13 would be safe so far as drying out is concerned. A shallow foundation is consequently as good here as one deeper. As will be seen from the plans, the required spread of foundation necessitated extending the concrete down to a point well below high water. (See Fig. 7.)

In considering the loads on piles and underlying strata, the eccentricity of loading was considered and the northwest piers were set over nine inches in order to bring the centers of columns in the axis of the freight house. In the other piers the greatest eccentricity is only $\frac{5}{8}$ inch. In the northwest abutment, Fig. 8, the thrust of the filling carries the line of pressure well forward toward the limit of the middle third. In the original design the piles were

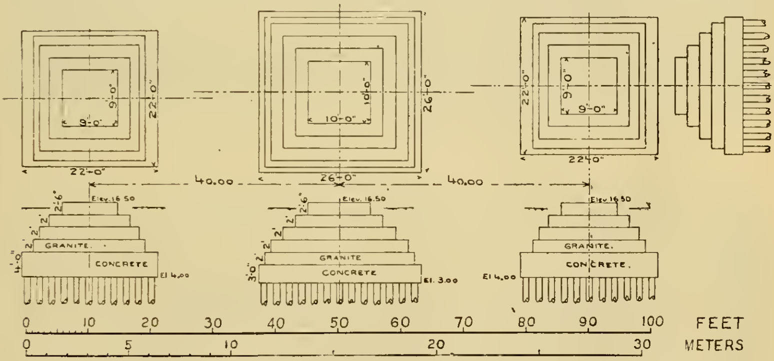


FIG. 7. MIDDLE PIERS.

spaced enough closer toward the front to bring the resultant of reactions coincident with the line of pressure. For constructive reasons this was changed before awarding the contract, and the piles were spaced two feet on centers, as in the other foundations, the result being that the piles near the toe of the abutment really carry about fifteen tons each instead of the twelve tons originally intended. Of course, they are capable of carrying much more than this.

In order to build the middle piers it became necessary to remove part of a freight house already built, and after the completion of the bridge to restore it to a condition of usefulness. The problem of water-proofing the roof was solved by constructing a nearly flat roof, with extensive flashing about the columns, the roof coming well below the rollers and movable parts of the bearing, and was covered with the usual tar and gravel.

The falsework was comparatively simple in plan and consisted of I beams and wooden stringers, carried on ordinary framed bents between tracks, in some cases spanning two tracks. Tracks were moved a few inches to equalize the clearance and lessen the chance of any collision between cars and bents. The traveler used was a substantial structure of wood and iron of sufficient span to cover two trusses. It was carried for the first half of the work on rails resting directly on the falsework. After the north and middle trusses had been swung, one leg was shortened to run on the top chord of the middle truss and cover the other half of the bridge. (See Figs. 9 and 10.)

The erection of the ironwork was carried on much the same as in similar work elsewhere, being notable principally for the great

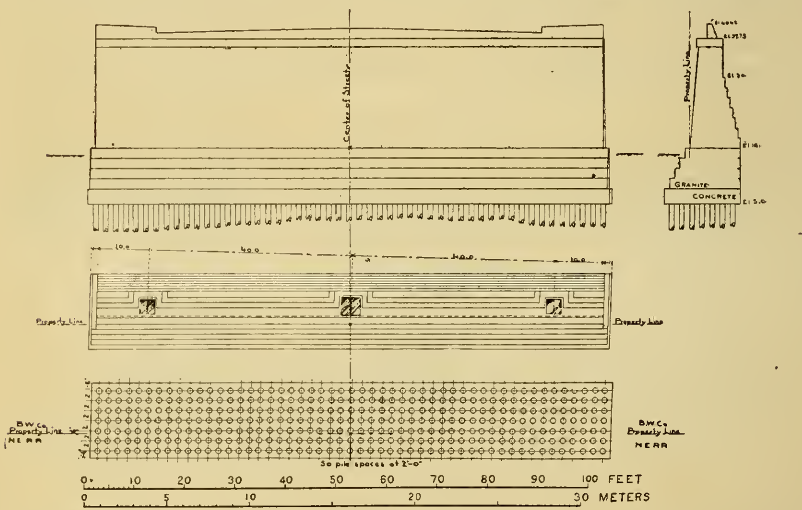


Fig. 8. Northwest Abutment.

weight of some of the top chord sections, some of which contained over two hundred square inches of metal in section. Some of the permanent stringers were placed and used to carry service tracks for distributing material to its place in the structure, but the floor was not permanently laid until the completion of the ironwork.

The provision and treatment of the lumber deserves some passing mention, illustrating as it does a radical change which is or has been taking place in the lumber business. This lumber was cut not far from Norfolk, Va., and treated at the Old Dominion Creosoting Works at that city. We are accustomed in this part of the world to think that the heaviest and most difficult work is done by the most modern establishments, as in case of steel bridges and

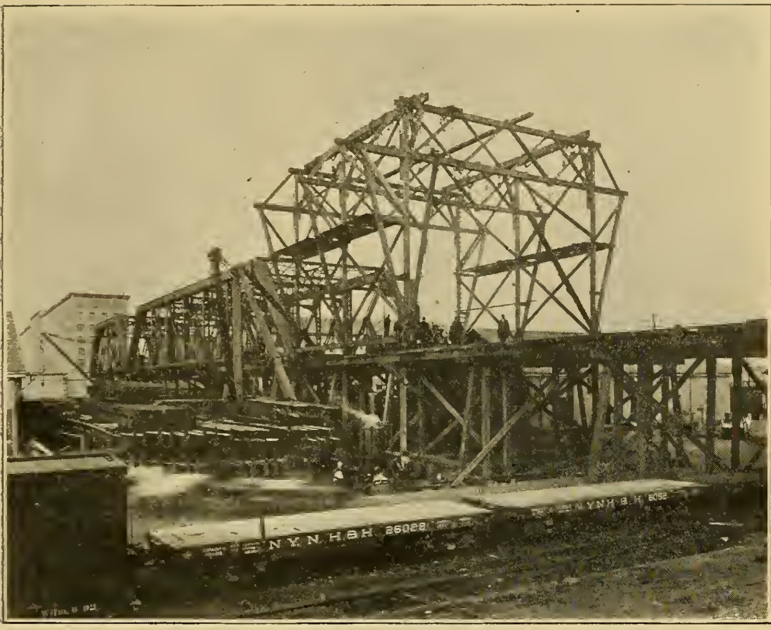


Fig. 9. Traveler and Falsework.

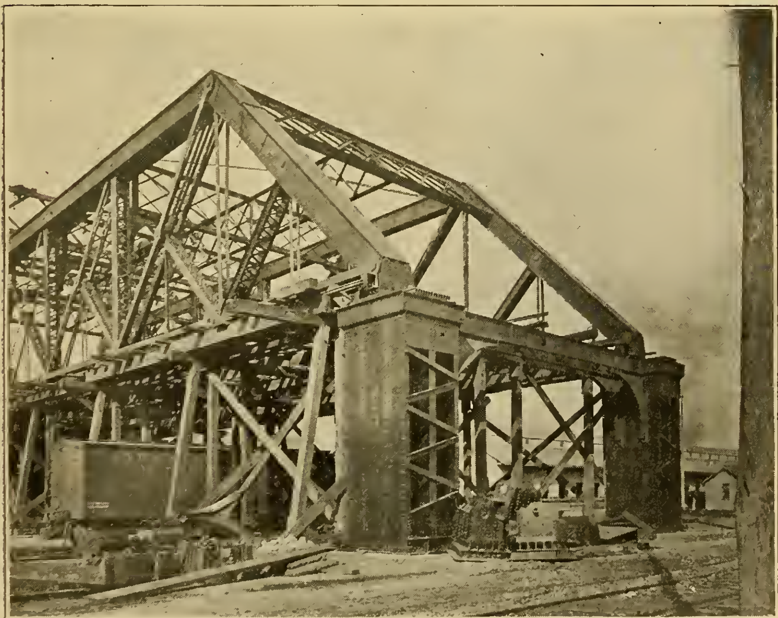


Fig. 10. Typical Truss and Columns.

heavy machinery. In the later lumber mills, however, this rule does not hold, the reason being that modern mills are generally run on comparatively short logs, and long sticks have to be sawed on more ancient machines. The later mills have the carriage operated by a direct steam cylinder, the piston being attached directly thereto.

There are several such mills in the vicinity of Norfolk, in which band saws are used, and the celerity with which logs in the water are transformed into lumber, sorted and piled ready for shipment, forms a marked contrast to older methods. Very little manual labor is employed. It is undoubtedly owing to the limited demand for long timber that these mills confine themselves to the shorter lengths.

As nearly half the lumber in the Summer street bridge is in 6″ x 12″ x 36′ sticks, it was necessary to obtain it from country mills, most of which, in that region at least, are run with the usual Southern disregard of hurry, so the delays in delivery at the creosoting works were both continuous and vexatious. This lumber being furnished under the main contract for the steel bridge, most of the vexation fell upon the local sub-contractor, who was no doubt accustomed to it.

The process of creosoting, while simple enough to one who has made a study of the subject, is not, however, at all well understood, as is attested by the commercial success of various washes and so-called paints, which can at best only temporarily retard decay.

There is plenty of information in print bearing on the subject, but so effectively scattered through various issues of many periodicals that one must be exceptionally well read to even know of its existence, much more to know where to look for it.

In brief, the process used in this case was as follows: First, the lumber was inclosed in a retort and steamed, first with saturated steam, to open the pores of the wood and dissolve most of the putrescible and soluble materials which nourish the bacteria, to whose presence decay is largely due; later by superheated steam, which removes the turpentine and other volatile substances from the wood, at the same time destroying any bacteria already present.

Second, the air, steam, water, turpentine, etc., are removed by air pumps, the temperature being meanwhile maintained by steam pipes in the retort, the exhausting process being continued several hours until the exhaust from the pump shows no trace of turpentine.

Third, the retort is filled with the dead oil from the storage tanks, and enough more is forced in to fill the requirements of the

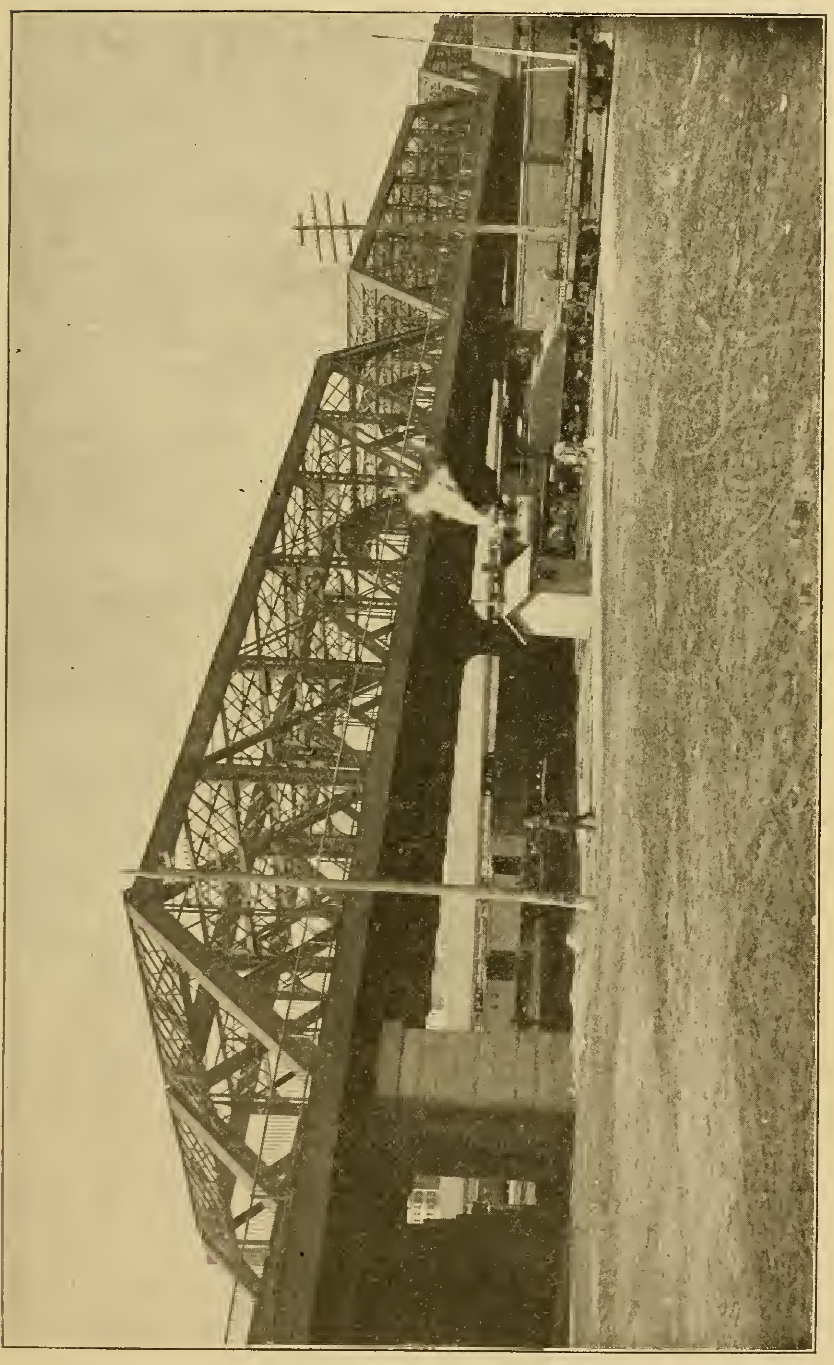


Fig. 11. General View Summer Street Bridge over New York, New Haven and Hartford Railroad.

specifications, in this case ten pounds per cubic foot of lumber. The oil is then forced back into the tanks and the retort opened.

The oil used on this work gave an average analysis as follows:

Water	0.02
Lower phenols distilling at 410° F.	0.07
Naphthalene distilling at 520	0.63
Higher phenols distilling at 610	0.12
Anthracin distilling at 680	0.09
Red oil and pitch distilling above 680 F.	0.07
Specific gravity at 60° F = 1.063. Liquid at 94° F.	1.00

This oil is imported from England, and is superior to American oil in percentage of naphthalene, our oil containing only about 40 per cent. As naphthalene is the active preservative agent, English oil is much preferred. It is of course not easily procurable away from the Atlantic coast, and even there is often costlier than American oil.

The water-proofing between the plank and the paving is practically a tar and gravel roof.

The paving is essentially similar to that of any street, and the sidewalks are asphalted directly on the plank.

Some of the quantities used were as follows: Paving, 6000 square yards; sidewalks, 1900 square yards; lumber, 675,000 feet board measure; iron, 6,700,000 pounds; masonry, 2300 cubic yards; piles, 1700; concrete, 900 cubic yards; excavation, 5000 cubic yards.

A general view of the completed structure is shown in Fig. 11.

Association of Engineering Societies.

Vol. XXVII. JULY, 1901. No. 1.

PROCEEDINGS.

Boston Society of Civil Engineers.

Boston, Mass., June 19, 1901.—A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 7.50 o'clock P.M., President Lawson B. Bidwell in the chair. Thirty-two members and visitors present.

The record of the last meeting was read and approved.

The Secretary read a memoir of John C. Haskell prepared by a committee of the Society consisting of Messrs. I. K. Harris and E. F. Dwelley.

On motion of Mr. Holmes, the thanks of the Society were voted to Messrs. Holbrook, Cabot and Daly for courtesies extended to the members on the occasion of the visit to the new Cambridge Bridge on June 11, 1901.

The Secretary read a short paper by Laurence Bradford, member of the Society, entitled, "Engineer Corps of the U. S. Army."

The regular paper of the evening was then read entitled "Summer Street Viaduct, South Boston," by Mr. Herman K. Higgins. The paper was fully illustrated by lantern views. Mr. Higgins had also thrown on the screen a number of views prepared from photographs taken by him while on a trip in Europe, showing many interesting and novel bridges.

Adjourned.

S. E. Tinkham, *Secretary.*

ASSOCIATION
OF
ENGINEERING SOCIETIES.

VOL. XXVII. AUGUST, 1901. NO. 2.

PROCEEDINGS.

Engineers' Club of Minneapolis.

THE 144th regular meeting of the Club was held at 8 P.M. on May 20, 1901, at its permanent quarters in the County Commissioners' rooms, in the County Court House. Seven active members and one honorary member, Col. J. T. Fanning, present.

Reading of minutes was dispensed with. Mr. Fanning's paper on "Canals and Canal Devices" was discussed. Mr. D. C. Washburn was elected to active membership. and the name of H. D. Lackore, electrician with the Minneapolis General Electric Company, was proposed. The new constitution and by-laws of the Club, as amended, were then read and adopted. Mr. Sublette was appointed as a committee of one to induce engineers at Duluth, Minn., to form an engineering association.

Adjourned.

EDWARD P. BURCH, *Secretary.*

CONSTITUTION AND BY-LAWS OF THE ENGINEERS' CLUB OF MINNEAPOLIS.*

ARTICLE I.

NAME, ETC.

The name, style and title by which this Society shall be known will be the "Engineers' Club of Minneapolis" (that is to say, Minneapolis, Minnesota). This Constitution and By-Laws appended to same are hereby enacted for the government of the Club.

ARTICLE II.

OBJECTS AND PURPOSES.

The object of the Club will be to discuss the various subjects embraced in the term engineering; to further the more perfect understanding of the dif-

*This Constitution and By-Laws was read and adopted at the regular meeting of the Engineers' Club of Minneapolis, held May 20, 1901, that being the 144th meeting of the Club. Read by the President, Wm. W. Redfield, who was also chairman of committee, appointed by the previous President to draft a new Constitution and By-Laws.

ferent methods, appliances and materials in current use; to examine into any or all achievements and failures in engineering work, and thus aid in the professional improvement of members; in promoting the general benefit of the public; and also in facilitating social intercourse among engineers.

ARTICLE III.

ELIGIBILITY.

Civil, mechanical, electrical and other engineers, and any interested in the advancement of engineering, who shall have attained the age of twenty-one years, and who are known to be in good standing, shall be eligible as members of either class, as hereinafter defined.

ARTICLE IV.

GOVERNMENT.

The government of the Club shall consist of a President, Vice-President, Secretary, Treasurer and Librarian, who shall be elected by ballot by a majority of the voters present at the Annual Meeting of the Club, and who shall hold their offices until others are elected in their stead. Any vacancy occasioned by resignation, death or otherwise, may be filled (by a special election held in the same manner as the above election) at the next regular meeting, after due notice to all voters of such vacancy.

The duties of the government shall be to have a general oversight of the affairs of the Club; to provide for literary exercises or programs of the meetings, and to arrange for any special function that may occur; in all of the above, they may be assisted by, or their powers delegated to the Committee on Entertainment. Furthermore, if found advisable, the offices of Secretary and Treasurer may be filled by the same person. As such combination would cause the government to consist of only four (4) active members, it would be necessary that a fifth member of the government be chosen at the same time and in the same manner as that of the election of the other officers; this extra office only holds valid as long as the offices of Secretary and Treasurer are so combined.

ARTICLE V.

FINANCE COMMITTEE.

The Finance Committee shall be composed of the five members of the government, together with two (2) other active members of the Club, each chosen by a majority of the votes cast by ballot at the Annual Meeting of the Club, or at any regular meeting, as soon as practicable after the adoption of this Constitution. They shall hold office until others are elected in their stead. The duties of this committee shall be to recommend to the Club any special assessments or appropriations for specific purposes; and to attend to any special financial business of the Club.

ARTICLE VI.

DUTIES OF OFFICERS.

SECTION 1. *President.* The duty of the President shall be to attend and preside at all meetings of the Club; to appoint all committees (except that of Finance), as follows: At each Annual Meeting, immediately after the termination of the election of all officers, the Finance Committee, and all Representatives to the Association of Engineering Societies, the incoming

President shall appoint the Standing Committees on Membership and Enterment, and also such other additional standing committees as may be deemed necessary, the same shall also be done at any regular meeting after the adoption of this Constitution. Each of these standing committees to consist of three (3) active members (not officers nor those serving on Finance Committee). The members of standing committees serve for one year, or until their successors are appointed. Other special committees may at any time be appointed, such special committees only serving long enough to accomplish the purposes for which they were appointed.

The President shall also countersign all the bills against the Club before they are paid; he shall make an advisory message and report upon the general condition of the Club at the Annual Meeting after each presidential term; he shall also make a brief inaugural on assuming the chair when not his own successor; he shall notify the Vice-President of any intended absence of himself from any meeting of the Club; and also notify the Secretary of any special meeting to be called.

SEC. 2. *Vice-President.* The duty of the Vice-President shall be to preside at all the meetings at which the President is unable to be present; and to be President *pro tem.* whenever the President is absent from the city.

SEC. 3. *Secretary.* The duty of the Secretary shall be to be present at all the meetings of the Club; to record the proceedings of each meeting in a minute book, and to read the minutes of any meeting at the next regular meeting held. He shall see that copies of such instructions as are recorded in the minutes, and that refer to any officer, committee, or member are sent to the proper parties. He shall read the names of such candidates as may be proposed, in correct form, for membership, as early as one (1) regular meeting previous to the one on which the election of said candidates is to occur. He shall notify each and every member at least three (3) days in advance of the date set for any regular meeting; but notice of the date set for the Annual Meeting shall be sent to each and every member at least one week in advance of the date set for said Annual Meeting. At this Annual Meeting he shall make a report of the preceding year. Notifications of special meetings are to be sent to active members only; unless some special reason requires the presence of any or all corresponding and honorary members, in which case the members concerned are also to receive notifications. It will also be the duty of the Secretary to promptly forward a properly condensed copy of the proceedings of every regular and important special meeting to the Association of Engineering Societies for publication in their journal; this means also a copy of any paper or communication read by any member at any meeting, and recommended by the Club for publication in said journal; also to notify the city papers of the date of any intended meeting. In consideration of the personal time necessarily devoted by him to the affairs of the Club, the Secretary is exempt from all dues while holding said office. If the duties of the Secretary should at any time become so great as to make it necessary, he may, with the approval of a majority of active members present at any regular meeting, appoint any active member (not a member of the Finance Committee) to be Assistant Secretary, said Assistant Secretary to act as Secretary during the absence of that officer, but shall neither be considered as an officer, nor as a member of the Government nor Finance Committee. His term shall always expire at the Annual Meeting following his appointment and confirmation. In case the offices of Secretary and Treasurer

are combined, according to Article IV of this Constitution, the Assistant Secretary shall also be Assistant Treasurer.

SEC. 4. *Treasurer.* The duty of the Treasurer shall be to keep a ledger account of all financial transactions of the Club with every member, and others indebted or credited; to cause the Secretary to send to each newly elected member a receipt for his initiation fee, and to cause the Secretary to send receipts for other dues from all members on payment of same, and to cause the Secretary to notify each member at least two weeks in advance of the date on which any dues are payable.

He is himself to notify each member who fails to pay his dues on the date called for, and failing to receive said delinquent dues within thirty (30) days after such notice has been sent, he is to hand their names to the Finance Committee. He is to deposit any surplus funds of the Club in such bank or banks as the Finance Committee shall direct, and to make such investments as the Finance Committee, on ratification by the Club, may determine. He is to pay all bills against the Club that are countersigned by the President, and to give receipts for all moneys paid to him, to whomsoever said receipts are due. He is to keep an accurate account of all his transactions for the Club, and must submit an annual financial report. If found expedient, at any time, either temporarily or permanently, the offices of Secretary and Treasurer may be filled by the same person, in accordance with Article IV of this Constitution.

SEC. 5. *Librarian.* The duty of the Librarian shall be to take entire charge of the library of the Club, and to see that all books and pamphlets and maps and other library property are marked with the name of the Club, and numbered and recorded in a catalogue. In respect to the management of the library, he shall conform to such regulations as may be prescribed by the Club.

ARTICLE VII.

AUDITOR.

At each Annual Meeting of the Club the incoming President shall appoint an Auditor whose duty shall be to audit the accounts of the Treasurer for previous fiscal year up to the date said Auditor is appointed, and then certify as to the accuracy of the accounts.

ARTICLE VIII.

REPRESENTATION IN THE ASSOCIATION OF ENGINEERING SOCIETIES.

In order that the Club may have an organ to represent it in the matter of publishing its proceedings or any communications furnished by members of the Club, the Club has affiliated itself with what is called the "Association of Engineering Societies." This Association publishes a journal in which appear the proceedings of and papers or other communications furnished by the members of the component societies. Each Society is entitled (according to the number of members composing the same), to send one or more of their active members as Representatives to said Association. Accordingly, at each Annual Meeting of this Club, after the election of the sixth and seventh members of the Finance Committee, any active member or members as required (other than those on Finance Committee) may be elected by ballot (in the same manner as are the officers) for Representative or Representatives to the Association of Engineering Societies.

ARTICLE IX.

ADMISSION, ELECTION AND DUTIES OF MEMBERS.

SECTION I. *Active Members.* The name of every candidate for active membership shall be proposed by two (2) active members of the Club, and the signatures of the applicant and those of his two proposers shall be written upon the proper blank application furnished by the Secretary. This application, properly filled out and signed, shall be filed with the Secretary, and accompanied with the initiation fee. The Secretary, as soon thereafter as practicable will deliver to applicant a receipt for initiation fee, obtaining the receipt from the Treasurer on deposit of initiation fee with him. In case applicant fails of being elected into the Club, this receipt on indorsement by the Secretary, will become an order on the Treasurer for a refunding of the initiation fee.

At the next regular meeting of the Club, after receipt by Secretary of the application properly drawn up and completed, with accompanying fee, the Secretary will read the names of the applicants and their proposers, and blank ballots (with names of candidates and proposers placed thereon, and a place to cross off "Yes" or "No" printed opposite each candidate's name), must be sent to all active members not later than the day after the meeting. The ballots when properly marked and filled out, will be inclosed in ballot envelopes, sealed, and then promptly sent back to the Secretary before the following regular meeting. At the latter meeting the ballots will be opened before the Club, and a two-thirds vote of the entire ballots received (a quorum voting) will elect a candidate. At the close of said meeting the Secretary will furnish to each newly elected member a card or certificate of membership, signed by the President and Secretary of the Club. Every duly elected active member has full privileges of voting and holding office, and shall be liable for all his dues and special assessments, and shall be considered an active member, and so liable until his resignation has been sent to the Secretary and accepted by the Club; *provided, however,* that no resignation can be accepted until all dues in arrears be paid.

SEC. 2. *Corresponding Members.* Any person qualified for eligibility as mentioned in Article III, of the Constitution, and who does not desire to be an active member, may become a corresponding member in the same manner as provided for active members. They shall be voted for by active members only. Corresponding members have all the privileges of active members, except voting and holding office. They may, however, serve on any committee (except that of Finance), at the discretion of the President. If the Club so desires, corresponding members may vote occasionally on matters concerning particularly their class of membership; or on questions where expediency may call for their vote, but such vote shall only be given (on special assent of active members) to corresponding members present at any meeting at which such assent be given. They shall be subject to no dues except the initiation fee, and a nominal annual assessment, the amount of same to be determined upon by the Club.

SEC. 3. *Honorary Members.* Any engineer who has achieved marked distinction by reason of his professional attainments may be proposed in writing by two active members as an honorary member; said proposal having been read by the Secretary at any regular meeting. Notice must then be sent by Secretary to all active members absent from that meeting. At the following regular meeting the candidate proposed for honorary membership

may be elected by a unanimous *viva voce* vote of the active members present. Honorary members shall be exempt from all dues and assessments; shall not pay an initiation fee; may attend and participate in literary exercises at all regular meetings; join in all excursions or functions, but may not vote nor hold office, and shall not serve on any committee, except at the discretion of the President should expediency warrant it. The Club, if it sees fit, may establish a limit to the number of honorary members permitted to be in the Club; or to prescribe a limit to the number elected during any one year.

ARTICLE X.

QUORUM.

At any regular meeting of the Club five (5) active members shall constitute a quorum for the transaction of business.

ARTICLE XI.

ALTERATIONS TO THIS CONSTITUTION.

Any alteration to this or any preceding article of this Constitution, whether it be addition, subtraction, revision or amendment, may be made by a two-thirds vote of all the active members who vote upon the same; *provided* that a copy of each and every proposed alteration, together with a notice (stating the time set for said proposed alteration to be voted upon) shall have been sent to each active member at least one month before the time set for voting thereon. Each and every alteration as then proposed must be read by the Secretary before the Club at two consecutive regular meetings. Ballots may be opened after the discussion at the second reading.

By-Laws.

ARTICLE I.

REGULAR MEETINGS.

The regular meetings of the Club shall be held on the third Monday of each month in the year at 8 o'clock P.M. If, however, reasons of expediency occur for changing the day, week or hour, either or all may be so changed.

ARTICLE II.

ORDER OF BUSINESS.

The following Order of Business shall be observed at all regular meetings, unless set aside by a four-fifths vote of active members present; except the reading of the minutes, which is not to be omitted, except by a unanimous vote of those present.

1. The reading of the minutes of the previous meeting.
2. Reading proposals for new members; balloting for new members, previously proposed.
3. Unfinished business.
4. New business; reports of committees.
5. Literary exercises.

ARTICLE III.

SPECIAL MEETINGS.

The President may call a special meeting of the Club, when he deems it expedient, and shall be bound to do so at the written request of three (3) active members, stating the purposes of such meeting.

ARTICLE IV.

DONATIONS AND RECORD THEREOF.

A record of all donations to the Club, whether in money, books, maps, models or other articles of value, with the names of the donors shall be entered by the Secretary in a book provided for that purpose, and to be kept in the rooms of the Club; the articles themselves being turned over to the custody of the proper officers, and the Secretary shall acknowledge to the donors the receipt of the donations, with the thanks of the Club.

ARTICLE V.

VISITORS.

Any person, not a member, may be introduced to the rooms of the Club, or be invited to any of the regular meetings of the Club, by any member, and all visitors are requested to register their names in a book provided for that purpose.

ARTICLE VI.

CARE OF PROPERTY.

No property of the Club shall be removed from the custody of those to whom any such property is intrusted, until the trust is relieved by action of the Club.

ARTICLE VII.

RULES FOR LIBRARY.

The Librarian may make necessary rules for the use of the library, subject to the approval of the Club.

ARTICLE VIII.

ADDITIONS TO OR DUPLICATIONS OF BOOKS IN LIBRARY.

A book shall be kept by the Librarian in which members may enter the titles of any book or books they may wish to be added to the library or duplicated, and the Librarian is to report thereon for action of the Club at each regular meeting should occasion arise.

ARTICLE IX.

ACCESSIBILITY OF RECORDS.

The records of the Club shall at all times be accessible to any or all members, at seasonable hours.

ARTICLE X.

MANUSCRIPTS FOR PUBLICATION.

A copy of any communication from a member, if ordered to be printed by the Club shall be furnished to the Secretary by the author thereof on due notice to him by the Secretary.

ARTICLE XI.

LETTERS OF MEMBERSHIP.

Letters of membership shall be issued to any member of good standing who may wish to visit other similar Clubs or Societies in other cities.

ARTICLE XII.

DUES AND ASSESSMENTS.

The initiation fee shall be three (3) dollars, and *must* accompany every application for active or corresponding membership filed with the Secretary.

No annual dues are called for until the Annual Meeting following the payment of initiation fee. The initiation fee covers the cost to all active members of a subscription to the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES for the balance of the current year in which the initiation fee is paid. To active members the subscription is continued as long as annual dues are paid promptly.

Corresponding members, if they desire the JOURNAL are entitled to the same on payment of the subscription price of $3 per annum. To honorary members it is sent free, commencing at the time of their reception into the Club.

The annual dues for active and also for corresponding members will be as approved of by the Club, on recommendations made from time to time by the Finance Committee.

Special assessments are made to active members only; and then only after a two-thirds vote of the active members present at any regular meeting; *provided* that notice of recommendation of same by Finance Committee shall have been sent to *all* active members one month previous to the regular meeting set for vote upon said special assessment.

ARTICLE XIII.

MEMBERS DELINQUENT AS TO THEIR DUES.

Active or corresponding members who are delinquent in their dues for over six months, may, if the Club think expedient, be dropped from the rolls.

ARTICLE XIV.

EXPULSION.

A member may be expelled from the Club by a two-thirds vote of the active members present at any regular meeting, a quorum voting; a notice stating causes of such proposed expulsion having been sent by the Secretary, at least one month previous, to all active members, including the members proposed to be expelled; *provided always* that on written application to the Secretary said member will be given a hearing, before action is taken by the Club; *and provided also,* that no movement toward expulsion take place until after a formal resolution of censure has been passed by the Club upon the member proposed for expulsion.

ARTICLE XV.

BLANKS AND FORMS.

The Secretary shall provide for all necessary blanks and forms to be used by the Club, but the forms of application for membership and certificates of membership shall be approved of by a majority of votes of all the active members present at any regular meeting; *provided* that in sending notice of such meeting, the Secretary will state thereon the fact that such forms will be presented for approval.

ARTICLE XVI.

AMENDMENTS.

These By-Laws may be amended by a two-thirds vote of the active members present at any regular meeting, a quorum voting; *provided* that the amendments were proposed at the previous regular meeting, and that the proposed amendment or amendments be stated on the notices sent by the Secretary announcing the date of the regular meeting at which action upon such amendment or amendments is to take place.

PAST OFFICERS OF THE CLUB.

ENGINEERS' CLUB OF MINNESOTA.

Date of Election.	President.	Vice-President.	Secretary and Treasurer.	Librarian.
May 18, 1883	Andrew Rinker	Wm. de la Barre	Wm. A. Pike	Geo. O. Foss.
Jan. 25, 1884	Wm. de la Barre	Geo. W. Cooley	Wm. A. Pike	Geo. O. Foss.
Jan. 16, 1885	Geo. W. Cooley	E. T. Abbott	Wm. A. Pike	W. W. Redfield.
Jan. 8, 1886	D. P. Waters	E. T. Abbott	W. S. Pardee	W. W. Redfield.
Jan. 14, 1887	Geo. W. Sublette	John H. Barr	W. S. Pardee.	

THE MINNEAPOLIS SOCIETY OF CIVIL ENGINEERS.

Date of Election.	President.	Vice-Presidents.	Secretary.	Ass't Sec. and Treas.	Librarian.
Feb. 1, 1888	W. A. Pike	1st, G. W. Sublette 2d, E. T. Abbott..	W. S. Pardee	C. O. Huntress	W. W. Redfield.
Jan. 2, 1889	W. A. Pike	1st, G. W. Sublette 2d, F. C. Deterly..	W. R. Hoag	C. O. Huntress	W. W. Redfield.

ENGINEERS' CLUB OF MINNEAPOLIS, MINN.

Date of Election.	President.	Vice-President.	Secretary and Treasurer.	Librarian.
May 7, 1890	W. A. Pike	Wm. de la Barre	F. W. Cappelen	W. W. Redfield.
Jan. 15, 1891	W. A. Pike	T. P. A. Howe	F. W. Cappelen	A. B. Coe.
Jan. 7, 1892	W. A. Pike	W. W. Redfield	F. W. Cappelen	A. B. Coe.
Jan. 12, 1893	F. W. Cappelen	J. M. Hazen	Elbert Nexsen	A. B. Coe.
Jan. 15, 1894	F. W. Cappelen	J. M. Hazen	Elbert Nexsen	A. B. Coe.
Mar. 18, 1895	F. W. Cappelen	I. E. Howe	Elbert Nexsen	A. B. Coe.
Mar. 2, 1896	F. W. Cappelen	I. E. Howe	Elbert Nexsen	A. B. Coe.
Jan. 26, 1897	F. J. Llewellyn	I. E. Howe	Elbert Nexsen	A. B. Coe.
Feb. 14, 1898	F. W. Cappelen	I. E. Howe	Harry E. Smith	W. W. Redfield.
Apr. 10, 1899	F. W. Cappelen	E. H. Loe	Harry E. Smith	W. W. Redfield.
Jan. 22, 1900	G. W. Sublette	C. L. Pillsbury	Harry E. Smith	W. W. Redfield.
Jan. 15, 1901	W. W. Redfield	C. L. Pillsbury	Edward P. Burch	Jas. E. Carroll.

May 9, 1884, Club voted to join the Association of Engineering Societies.

MEMBERS OF THE BOARD OF MANAGERS, ASSOCIATION OF ENGINEERING SOCIETIES, WITH DATE OF ELECTION.

July 18, 1884, Geo. W. Cooley.
January 8, 1886, Geo. W. Cooley.
January 14, 1887, Geo. W. Cooley.
February 1, 1888, Andrew Rinker.
January 2, 1889, Wm. de la Barre.
May 7, 1890, Andrew Rinker.
January 15, 1891, Andrew Rinker.
January 7, 1892, Elbert Nexsen.
January 12, 1893, Wm. A. Pike.
January 15, 1894, Wm. A. Pike.
March 15, 1895, Wm. A. Pike.
February 3, 1896, Geo. D. Shepardson.
January 26, 1897, Geo. D. Shepardson.
February 14, 1898, Geo. D. Shepardson.
April 10, 1899, Geo. D. Shepardson.
January 22, 1900, W. R. Hoag.
January 15, 1901, W. R. Hoag.

ORIGINAL CHARTER MEMBERS.

Andrew Rinker, Great Falls, Mont.
Wm. de la Barre, Supt. St. Anthony Water Power Co., Minneapolis, Minn.
†Wm. A. Pike, State University, Minneapolis, Minn.
†Jas. Waters, Chief Engineer Board of Water Commissioners, Minneapolis, Minn.
Wm. W. Redfield, Engineer Water Department, Minneapolis, Minn.
Geo. O. Foss, Civil Engineer and Contractor, Minneapolis, Minn.
I. C. Patterson, Civil Engineer.
H. M. Waitt, Civil Engineer.
E. T. Abbott, Civil Engineer, Minneapolis, Minn.
W. E. Weston.
G. W. Sturtevant.
S. H. Baker.
Geo. H. White.
C. E. Sprague.
W. D. Van Duzee.
Geo. W. Cooley, Civil Engineer and Surveyor, Minneapolis, Minn.
M. D. Rhame, Civil Engineer C. M. and St. Paul Ry.

†Now deceased.

Association of Engineering Societies.

Vol. XXVII. SEPTEMBER, 1901. No. 3.

PROCEEDINGS.

Boston Society of Civil Engineers.

Boston, Mass., September 18, 1901.—A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 7.50 o'clock p.m. President Bidwell in the chair; forty-five members and visitors present.

The record of the last meeting was read and approved.

Messrs. Charles H. Dodd, Hardy S. Ferguson, Walter B. Foster and Harry A. Storrs were elected members of the Society.

On motion of Mr. Higgins, the thanks of the Society were voted as follows: To Messrs. Winston Brothers and Locher, contractors at the Wachusett Dam, Clinton, for courtesies shown at the excursion on July 24; to Mr. E. B. Winslow, of the Portland Stoneware Co., for courtesies and generous entertainment during the excursion to Portland on August 17, and to the Fore River Ship and Engine Co., for courtesies extended this afternoon during the visit to the plant of that company.

In connection with the vote of thanks to Mr. Winslow, the President thought a concise statement of what we engineers learned on our visit to Portland, Me., of August 17, 1901, about the Portland Drain and Sewer Pipe, would be of interest to all engineers, as in almost all construction the matter of drainage must be taken into account, and he therefore submitted the following notes:

First, we found that about three-quarters of the clay used came from New Jersey, at a far greater cost than the remaining one-quarter, which came from ground within easy reach of the works; and that the New Jersey clay made a body that would, in stacking and burning, keep its shape, but pipe made wholly from the home clay would melt down; and that a mixture of the two gave the best results, as explained. From this it would appear that if the pipes were, when burned, in proper form, too much of the cheaper clay had not been used. Of course, the manufacturer would use as much of the cheaper clay as possible and make a perfect pipe; and, as this clay causes, when baked, the vitrification, the purchaser would, if he had no other guarantee, be quite sure that, if the pipe was in good shape and well baked, requiring only a simple inspection, he would get a strong and durable pipe. We also found that those pipes which were placed next the walls of the kiln, although when baked in windy or bad weather, would show a little lighter in color, the vitrification was even

deeper than on those of a darker color, which is an indication that they might be even more durable when light in color.

Further, we found that where formerly a large part of the work was piecework, now very nearly all is daywork; and that to obtain the most perfect product a very much less number of pieces were required for a good day's work from a workman than were formerly turned out under the piece system, notably in one case that of fitting and placing the branches, about 125 being expected where the same workman had under the piece system finished about 275 in a day, the object being to have each pipe as perfect as possible when it left the manufactory.

We also found that a die was partly made for producing a thirty-six-inch pipe, three feet in length and three and one-quarter inches in thickness. The use of vitrified pipe is constantly increasing, and we were told by the City Engineer of Portland that, notwithstanding the largely increased plant and output, he could not get a promise of delivery of twelve-inch pipe in less than three weeks. One of the reasons for this increased use over brick for sewers or drains is the smoother surface making less danger of clogging, and the fact that they can be placed by an intelligent man who could not command more than one-half a brick mason's wages.

As to the paving brick, we found them quite strong and apparently made and baked with great care, and made a very neat pavement. Some of our party seemed to think it doubtful whether they would stand under our Boston trucking, which is said to be heavier than in almost any other city. They have, however, been in use under heavy traffic at some place in Portland for three years and with slight wear; but this paving we did not see. Although more readily laid than granite, it is yet to be determined whether they will replace granite where it can readily be obtained, although the cost is less per square yard. In such places where the granite could not be readily had, certainly it would seem that they will be used, and they would work in well and make very neat approaches to buildings and drives across sidewalks, etc.

Mr. R. S. Hale offered the following resolution, which was adopted:

Whereas, It is probable that the American Society of Mechanical Engineers will hold its semi-annual meeting of 1902 at Boston,

Resolved, That the Boston Society of Civil Engineers will cordially welcome the American Society of Mechanical Engineers to this city.

Resolved, That the Board of Government be authorized to appoint a committee of five which committee shall have power to fill vacancies and add to its numbers, to co-operate with the local members of the American Society of Mechanical Engineers.

The paper of the evening was read by Mr. Arthur S. Tuttle, entitled "The Abolition of Grade Crossings on the Providence Division of the New York, New Haven and Hartford Railroad between Boston and Dedham."

The paper was illustrated by numerous lantern slides. In the discussion which followed the reading of the paper, Messrs. Rollins, Fitzgerald and Tuttle took part.

On motion of Mr. Kimball, the thanks of the Society were voted to Mr. Tuttle for his very interesting paper.

Adjourned.

S. E. Tinkham, *Secretary.*

Engineers' Club of St. Louis.

529TH MEETING, SEPTEMBER 18, 1901.—Held at 1600 Locust street, President Spencer presiding. Attendance, twenty-four members and fourteen visitors. Minutes of the 528th meeting were read and approved. Minutes of the 312th and 313th meetings of the Executive Committee were read.

The applications for membership of Roderick H. Tait, Alexander S. Langsdorf, Benjamin Charles Milner, Jr., and Tyron Ervin Beebe were read and referred to the Executive Committee.

On ballot, John Innerarity Boggs was elected to membership.

A letter was read from a committee of the Missouri Historical Society with reference to securing among the buildings of the Louisiana Purchase Exposition a fireproof building to be used for housing the collections and libraries of the Missouri Historical Society, Academy of Science of St. Louis, and other scientific societies.

On motion of Mr. Ockerson, the following resolutions were adopted:

WHEREAS, It is understood that an effort is being made to secure, among the buildings needed for the Louisiana Purchase Exposition, one of fireproof materials, suitably located, and to be used after the Exposition for the housing in an accessible and instructive manner of the libraries and collections of the Missouri Historical Society, the Academy of Science of St. Louis, and other organizations devoted to history, archæology, natural history, and other pure and appli d sciences, and for meeting places for such organizations.

Resolved, That the Engineers' Club of St. Louis is heartily in favor of such effort and indorses the proposed ends, which, it is believed, are in the best interests of the community at large.

Resolved, further, That a committee of three be appointed by the chair without delay, authorized to represent this body, in connection with similar committees appointed by other organizations, in such action as may be necessary to secure the desired end.

Mr. J. A. Ockerson then read a paper entitled "The Mississippi River: Physical Characteristics and Methods of Improvements."

He gave a general description of the river and of the methods used to improve navigation and prevent overflow.

He gave statistics showing the traffic and tonnage on the river, and showed that while the traffic is now a much smaller percentage of the total of adjacent territory, it is still nearly as large as it was at its prime. The paper was accompanied by a large number of lantern slides, showing objects of interest along the river and illustrating methods used in its improvement.

On invitation of the president, Mr. A. V. A. Brueggeman, president of the Architectural Club, addressed the club with reference to obtaining downtown quarters in conjunction with the Architectural Club and the St. Louis Chapter of the American Institute of Architects.

Adjourned.

A light lunch was provided in the library room by the entertainment committee.

GEORGE I. BOUTON, *Secretary pro tem.*

Montana Society of Engineers.

A regular meeting of the Montana Society of Engineers was held in Rooms 16 and 17, Tuttle Block, Butte, Mont., on September 14, 1901. The following members were present: Messrs. Harper, Patterson, Blackford, Putnam, Blossom, McArthur, Strasburger and R. R. Vail. Visitors, Messrs. Summers and Brotherton. Mr. F. W. Blackford was elected chairman *pro tem.*

The minutes of the last meeting were read and approved.

Mr. Eugene Sickles then gave a very interesting talk on the subject of "Electrical Current Transmission."

Moved and seconded that the Society adjourn until 8 P.M., September 21, 1901. Carried.

On September 21, the Society met at their headquarters with the following present: Messrs. Blackford, Christian, Harper, Moulthrop, Leonard, Patterson, McArthur, Flood, Koberle, Dunshee and R. R. Vail. Mr. Christian, First Vice-President, in the chair.

A committee of three was appointed to nominate officers for the ensuing year as follows: Messrs. F. W. Blackford, C. W. Goodale and Samuel Barker, Jr.

A short discussion of the financial condition of the Society followed. Moved by Mr. Blackford and seconded by Mr. Harper, that the Secretary be instructed to prepare statement of accounts with an estimate of expenses and present to the trustees for their consideration. Carried.

Society adjourned.

Richard R. Vail, *Secretary.*

Association of Engineering Societies.

Vol. XXVII. **OCTOBER, 1901.** No. 4.

PROCEEDINGS.

Technical Society of the Pacific Coast.

Regular Meeting, August 2, 1901.—Called to order at 8.30 P.M. by Past-President C. E. Grunsky. The minutes of the last regular meeting were read and approved.

Dr. C. S. G. Nagel thereupon delivered a lecture on the mechanical structure of the eye, treating its anatomical and optical features, and explaining in detail the modern methods of eye operations. This subject was discussed by members present.

The President thanked Dr. Nagel in the name of the Society for his interesting and instructive lecture.

Adjourned. Otto von Geldern, *Secretary.*

Regular Meeting, August 15, 1901.—The Technical Society invited its members to visit the destruction of Arch Rock, in the harbor of San Francisco, which took place at 12.10 P.M. The members and their guests were conveyed in a steamboat to a point in the bay where the most advantageous view of the explosion could be had.

After the blast, the party was taken to the locality of the one-time formidable rock, upon which the steamboat returned to the wharf.

Otto von Geldern, *Secretary.*

Regular Meeting, September 6, 1901.—Called to order at 8.30 P.M. by Thos. Morrin. The news having been received, just prior to the meeting, of the attempted assassination of President McKinley, the desire was expressed that business only be transacted, and that all technical discussion be postponed.

Mr. Morrin called attention to the matter of the Technical Society transferring its rooms to the Mechanics' Institute Building and becoming a part of the institute, without losing its identity as a society or its membership in the Association of Engineering Societies. Every member of the Techncal Society would become a member of the institute, and have the benefit of the very extensive technical literature of the Mechanics' Library without any increase in dues, and without the loss of a single one of those advantages to which his membership in the Technical Society entitled him.

Mr. Irving, President of the Mechanics' Institute, explained at length the present condition of the institute, financially and socially, and indicated that the members of the Technical Society might become a very important element in the transactions of the institute, which, by reason of its great wealth, could offer them many advantages that the Society could not now afford.

There being but a small number present at this meeting, it was thought advisable to take no definite action, but to appoint an investigating committee of three or four members to meet a similar committee from the institute and submit to the Technical Society some formulated project by which an affiliation of the nature suggested this evening might be consummated. Three members were appointed on this committee,—Stetson G. Hindes, J. G. H. Wolff and Hermann Kower, to which Mr. Luther Wagoner was added subsequently.

This committee is to report upon the probable result of such change, so vital to the interests of the Society, and to make a full statement to the Board of Directors, who will present the matter to the members of the Society if it be thought desirable to entertain the proposition.

Meeting adjourned.

Otto von Geldern, *Secretary.*

Regular Meeting, October 4, 1901.—Called to order at 8.30 p.m. by Vice-President Henry.

The minutes of the last regular meeting were read and approved.

The following applications were received and referred to ballot, having been approved by the Board of Directors:

Charles E. Wetherell, surveyor, of San Francisco, proposed by C. E. Grunsky, H. D. Connick and F. C. Herrmann.

Dr. C. S. G. Nagel, scientist, of San Francisco, proposed by Otto von Geldern, D. C. Henny and J. H. G. Wolf.

The Chairman stated that this meeting had been set aside for the purpose of discussing the important proposition of affiliating with the Mechanics' Institute, and that the committee having investigated the proposition upon its advantages and disadvantages, would report at once to bring the matter intelligently before the meeting for earnest discussion.

The committee thereupon reported as follows:

"San Francisco, Cal., October 4, 1901.

"*To the President and Members of the Technical Society, San Francisco, Cal.*

"Gentlemen: Your committee appointed at the regular September meeting for the purpose of investigating the conditions and desirability of affiliating with the Mechanics' Institute has the honor to report as follows:

"Two meetings have been held, the first on September 11 in these rooms, at which the essential points to be observed in considering the proposition were carefully gone over and noted. One week later our committee met the Library Committee at the Mechanics' Institute rooms and discussed minutely the conditions and requirements pertaining to the proposition of affiliation.

"We found that the new policy of the Institute favored the fostering of all scientific and engineering societies of the city. The Institute expects in the near future to put up a new building in which adequate provision will be made for any such societies.

"The absolute identity of the Technical Society, which is of supreme importance, would be preserved, and our relation to the Institute would be that of a tenant. The proposition as outlined would be to give up these quarters and move to the Institute, thus avoiding paying rent. All regular

active members and the resident associate members would be entitled to all the privileges of Institute membership, and in fact would be regular members, for which the Technical Society would pay 50 cents per month for each of these members. They would have a vote in the affairs of the Institute and would be entitled to take books from the library.

"It is found that the amount saved in rent, etc., would just about equal the amount to be paid the Institute in membership dues, so that the Society would be at no greater expense than at present and would be able to give its members additional privileges and benefits.

"This Society would manage its own affairs exactly as at present, collect its dues, and continue to furnish its members with copies of the JOURNAL OF THE ASSOCIATION OF ENGINEERING SOCIETIES, and it would still remain a member thereof.

"The assembly hall in the Library Building is a large-sized room, and well adapted to our purposes, and could always be had on the regular meeting night,—viz, the first Friday of each month, as well as at other times if desirable. There is also a room available as an office where the records of the Society could be kept, and its business transacted.

"The Institute desires to keep up its technical and scientific side, as there is a great tendency for the fiction portion to be always in the supremacy. And it is believed that by taking in our Society, our members will be encouraged to take an active part in the affairs of the Institute, and will be able to add to its success as one of the prominent institutions of San Francisco.

"It would also appear that a number of new members might be acquired who are already Institute members, and who would willingly pay the 50 cents additional dues required by the Technical Society. This would apply especially to the younger men, who might not feel like maintaining membership in both organizations as at present at an expense of $1.50 per month.

"As about one-half of the Technical Society members are already members of the Mechanics' Institute, these would save their present Institute dues, amounting to 50 cents per month. Non-resident members and non-resident associate members who now pay dues of 50 cents per month into this Society would not be full members of the Institute, and could not take out books; but they would have the JOURNAL and the privilege of attending all meetings and voting in the Technical Society just as at present.

"The Society would have to pay an admission fee of $1 for each member not already a member of the Institute. This would amount to about $35, and could be paid out of the funds now in the treasury.

"Our books, while always remaining our property, could be put upon the shelves of the library for circulation, and any of our periodicals not already possessed by the Institute would be bound at their expense.

The committee has carefully considered the various phases and believes the advantages to be much greater than any disadvantages, and would recommend the affiliation of the Technical Society with the Mechanics' Institute.

"STETSON G. HINDES,
"J. H. G. WOLF,
"HERMANN KOWER,
"LUTHER WAGONER,
"Committee."

A discussion was then started, which was opened by Mr. S. C. Irving, President of the Mechanics' Institute, who held out the advantages that would be gained by the Society in affiliating with the Institute, whose policy is to foster mechanical art and engineering science, and who had ample funds for the purpose of inagurating serious work along lines of technical importance. Other members followed, the general opinion being expressed that the proposition had its merits, and that there were many mutual advantages and possibilities.

President Marx expressed in writing to the Secretary his entire sympathy with the project, taking it for granted that the base of the affiliation would be that outlined in the circular letter to members dated September 26, 1901.

It was finally moved by Mr. Grunsky, and duly seconded, that it *be* the sense of this meeting that the Technical Society affiliate with the Mechanics' Institute on the lines indicated by the committee in its report, and that a copy of this report, together with a statement of the proceedings of this meeting be mailed to every member of the Technical Society, with a request for an individual vote in favor of or against the proposition. Motion was carried.

It was then moved by Mr. Wagoner, and duly seconded, that if the vote upon this question be favorable, the Board of Directors be instructed to carry out the work of the proposed affiliation in the manner outlined by the special committee, which is to have further time and continue its work until the rendering of the final decision. Carried.

Meeting thereupon adjourned.

Otto von Geldern, *Secretary.*

Engineers' Club of St. Louis.

530th Meeting, October 2, 1901.—Held at 1600 Locust Street at 8 p.m.; President Spencer presiding. Attendance, thirty-three members and twenty-five visitors. Minutes of the 529th meeting were read and approved. Minutes of the 314th meeting of the Executive Committee were read.

The applications for membership of Charles Wm. Roehrig, George Eugene Wells and C. D. Purdon were read and referred to the Executive Committee.

On invitation of the President, Mr. A. V. A. Brueggeman, President of the Architectural Club, addressed the Club, giving further information with reference to obtaining down-town quarters in conjunction with the Architectural Club and the St. Louis Chapter of the American Institute of Architects.

On motion of Mr. Bryan, which was duly seconded, the Executive Committee of the Engineers' Club was authorized to confer with the St. Louis Architectural Club and with the St. Louis Chapter of the American Institute of Architects regarding arrangements for down-town quarters, and requested to report at the next meeting. The motion was carried.

Mr. William H. Bryan then read the paper of the evening, entitled "Smoke Abatement in St. Louis." Mr. Bryan gave a brief history of the movement in St. Louis, and of the prominent part taken in it by the Engineers' Club. He stated clearly the difficulties which have been encountered and the results which have been accomplished to the present time.

Regarding fuels it was shown that the cost of smokeless fuels was beyond the reach of the ordinary consumers and that the problem resolved itself into burning the ordinary fuels smokelessly.

Smoke-preventing devices were discussed and classified as follows: Steam jets, coking furnaces or fire brick arches, down-draft furnaces, automatic stokers and powdered fuels. Each in turn was described and illustrated by numerous lantern slides. It was stated that while no one device was applicable to all furnaces, some one or more would be found for each furnace which would work successfully, providing it was intelligently operated and maintained.

The hope was expressed that the problem would be so effectively handled by the World's Fair authorities as to give an object lesson to the world.

Discussion was participated in by Messrs. C. E. Jones, Joseph A. Wangler and Mr. Dan. C. Nugent and Eugene McQuillin, of the Citizens' Smoke Abatement Association.

Adjourned to the library room, where lunch was served.

E. B. Fay, *Secretary pro tem.*

531st Meeting, October 16, 1901.—Held at 1600 Locust Street at 8 p.m.; President Spencer presiding. Attendance, thirty-four members and seven visitors. Minutes of the 530th meeting were read and approved.

Applications for membership of Ben F. Affleck and James C. Travilla were read and referred to the Executive Committee.

On ballot the following were elected to membership: Charles W. Roehrig, George E. Wells, Charles D. Purdon, Tyron Ervin Beebe, Roderick H. Tait, Benjamin C. Milner, Jr., Alexander S. Langsdorf.

Mr. J. H. Kinealy, for the Executive Committee, made a report regarding securing downtown quarters in conjunction with the St. Louis Architectural Club and the St. Louis Chapter of American Institute of Architects. He stated that suitable quarters could be obtained in the Howard Building, and submitted a proposed plan of new quarters, together with information regarding the sizes of rooms as compared with the present quarters, probable cost, etc. He stated that the members of the Executive Committee were unanimously in favor of making the move and of making arrangements with the Clubs mentioned. After considerable discussion motion was made and carried to defer final action until the next meeting and make the question a special order of business at the next meeting, all members of the Club being notified.

The subject of the evening was a paper by Mr. George I. Bouton on "Stair Lifts." A detailed description of the various lifts which are manufactured and used in the United States was given. The paper was illustrated by numerous lantern slides, showing the various kinds of lifts in operation in department stores and elevated railroad stations. A statement was given regarding the power required for operating and the cost of installation. Discussion was participated in by Messrs. Ockerson, Borden and Bouton.

On conclusion of the paper letters were read from the Public Welfare Commission, addressed to the President, as the Club's representative on the commission, requesting such service as could be rendered in aid of the proposed charter amendments, and requesting the signature of as many voters as could be reached to the appeal which accompanied the letter. President Spencer stated that copies of the appeal would be found on the Secretary's table in the library room, and he hoped that all members of the Club would sign it.

Adjourned to the library room, where lunch was served.

E. B. Fay, *Secretary pro tem.*

Boston Society of Civil Engineers.

Boston, Mass., October 16, 1901.—A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 8 o'clock p.m.; President L. B. Bidwell in the chair; forty-eight members and visitors present.

The record of the last meeting was read and approved.

Messrs. E. Roland Simpson and John B. Wright were elected members of the Society.

A communication was read from the Secretary of the American Park and Outdoor Art Association in relation to its proposed annual convention to be held in Boston in August, 1902, and suggested that some uniform action might be taken by the several kindred organizations in this neighborhood in the way of entertainment during the convention. On motion of Mr. French, the whole subject was referred to the Board of Government.

On motion of Mr. Higgins, the thanks of the Society were voted to the civil engineers located at the Navy Yard for courtesies shown the members of the Society during the visit to the Navy Yard this afternoon.

Prof. William Carey Poland, of Brown University, was then introduced and gave a very entertaining and instructive talk, illustrated by numerous lantern slides, entitled "The Development of Artistic Forms in Architecture from Elements of Construction."

At the conclusion of the talk, on motion of Mr. Rice, the thanks of the Society were voted to Professor Poland for his interesting lecture.

Adjourned. S. E. TINKHAM, *Secretary.*

Association of Engineering Societies.

Vol. XXVII. NOVEMBER, 1901. No. 5.

PROCEEDINGS.

Engineers' Club of St. Louis.

532D Meeting, November 6, 1901.—Held at 1600 Locust Street at 8.15 P.M.; President Spencer presiding. Attendance, thirty-seven members and six visitors. Minutes of the 531st meeting were read and approved. Minutes of the 315th meeting of the Executive Committee were read.

Mr. Ockerson, chairman of the committee appointed to confer with the committees of the Missouri Historical and other societies regarding obtaining a permanent fire-proof building from the Louisiana Purchase Exposition Company for housing libraries, etc., reported that a meeting of the committees which had been called for some days before had been postponed indefinitely, and from what he could ascertain they had no building in mind, and if such a building was obtained it would be located in Forest Park.

Mr. Kinealy, for the Executive Committee, made a report regarding securing downtown quarters, repeating the report made at the last meeting and also giving additional information regarding the cost of furnishing the new quarters. After considerable discussion a motion was made by Mr. Bryan, which was amended by Mr. Flad; the amended motion was as follows: "That the recommendation of the Executive Committee in the matter of securing downtown quarters in association with the St. Louis Chapter of the American Institute of Architects and the St. Louis Architectural Club be approved, and that the Executive Committee be authorized to arrange all necessary details." This motion was seconded, but before it was put to a vote there was further discussion by Messrs. Wheeler, Ockerson and Bryan, after which the motion was voted upon and carried.

The application for membership of Alvin D. Reed was read and referred to the Executive Committee. On ballot Messrs. Ben F. Affleck and Jas. C. Travilla were elected to membership.

Owing to the unavoidable absence from the city of Mr. H. H. Humphrey, who was to have read a paper on "Uses of Beaumont Oil," Mr. Alex S. Langsdorf kindly addressed the Club on the subject of "Iron in Alternating Current Circuits." He discussed the curves of magnetization, loops due to hysteresis, and described a simple method of obtaining the co-efficient of self-induction. Discussion was participated in by Messrs. Kinealy, Klauder and Langsdorf.

Adjourned to the library room, where lunch was served.

E. B. Fay, *Secretary pro tem.*

Technical Society of the Pacific Coast.

Regular Meeting, November 1, 1901.—Called to order at 8.30 p.m. by President Marx.

The minutes of the last regular meeting were read and approved.

The tellers appointed opened the ballots, and counted the vote cast on the proposition to affiliate with the Mechanics' Institute, on the lines indicated in the Special Committee's report, circulated to members, under date October 15, 1901, with the following result: Total vote, 77; for, 75; against, 2.

The President thereupon declared the proposition carried, and instructed the committee to make all arrangements to enter upon this agreement by December 1, 1901.

The following were elected to membership upon a count of ballots: Chas. E. Wetherell, surveyor, of San Francisco; Dr. C. S. G. Nagel, scientist, of San Francisco.

Prof. F. G. Hesse delivered an address, demonstrating mathematically the "Efficiency of the Compound Centrifugal Pump."

A discussion followed, which was reported by the stenographer.

Meeting thereupon adjourned.

Otto von Geldern, *Secretary*.

Association of Engineering Societies.

Vol. XXVII. **December, 1901.** No. 6.

PROCEEDINGS.

Engineers' Club of Cincinnati.

125th Regular Meeting, Cincinnati, Ohio, June 20, 1901.—Dinner was served at 6.30 p.m.

The regular meeting was called to order at 8.00 p.m.; President Jewett in the chair, and fourteen members present.

Minutes of the meeting of May 23 were read and approved.

Resolutions on the death of Alfred Petry were presented by the committee as follows:

Death having removed one more name from the rolls of this Society, be it

Resolved, That we, the friends and fellow-members of Alfred Petry, place on record our sincere regret and feeling of deep loss sustained by his untimely death; further be it

Resolved, That we extend our heart-felt sympathy to his sisters; and, further, be it

Resolved, That these words be entered upon the minutes of this Society, and that a copy hereof be sent to his sisters;

which, on motion, was ordered received and spread upon the minutes of the meeting, and a copy forwarded to his relatives, as provided.

Mr. C. A. Keller, representative of the Scherzer Rolling-Lift Bridge Company, of Chicago, read a paper on "The Rolling-Lift Bridges at Cleveland, Ohio."

Mr. Keller described, with the aid of the stereopticon, the two railroad bridges, one a single leaf and the other a double leaf structure, recently constructed by his company over the Cuyahoga River at Cleveland, on the line of the C., C., C. and St. L. Ry. under the direction of Mr. G. W. Kittredge, chief engineer of that road. These bridges replace the old wooden swing bridges that had been in use for a number of years, and needing renewing, the rolling-lift bridge was selected as the best type filling all the requirements.

After a vote of thanks to Mr. Keller for his paper, and a discussion of the same, the Club adjourned.

J. F. Wilson, *Secretary.*

126TH REGULAR MEETING, CINCINNATI, OHIO. SEPTEMBER 26, 1901.—Postponed from the 19th on account of and out of respect to the death of President McKinley, whose funeral occurred on that date.

Supper was served at 6.20 P.M.

The regular meeting was called to order at 7.30 P.M. with President Jewett in the chair and nine members present.

Minutes of the meeting of June 20 were read and approved.

The following papers were read:

(*a*) Elevators. By O. F. Shepard, Jr., being an extempore talk on the subject of the construction and operation of elevators, principally electric, as practiced by the Warner Elevator Manufacturing Company.

(*b*) Operating Machinery by Electricity. By Louis E. Bogen, in which he showed the application of electric motors in the operation of machinery and machine tools.

After a short discussion of the subjects, as the hour was getting late, and a vote of thanks to the speakers, the meeting adjourned.

J. F. WILSON, *Secretary.*

127TH REGULAR MEETING. CINCINNATI, OHIO, OCTOBER 19, 1901.—Supper was served at 6.30 P.M.

The regular meeting was called to order at 7.20 P.M. with President Jewett in the chair, and ten members present.

Minutes of the meeting of September 26 were read and approved.

Mr. C. W. Johnson, chief draftsman of the engineering department of the Bullock Electric Manufacturing Company, favored the Club with a talk on the subject of "Indexing of Drawings," which comprised a thorough and interesting account of the very complete system of filing and indexing the large number of plans covering the great variety of work turned out by that company, and which contained much of interest to those present.

After a discussion of the subject and a vote of thanks to Mr. Johnson the meeting adjourned.

J. F. WILSON, *Secretary.*

128TH REGULAR MEETING. CINCINNATI, OHIO, NOVEMBER 21, 1901.—Dinner was served at 6.15 P.M. The regular meeting was called to order at 7.30 P.M., with President Jewett in the chair and eighteen members present.

Minutes of the meeting of October 19th were read and approved.

The minutes of the meeting of the Executive Board, held November 16th, were read, in which recommendations were made providing for the withdrawal of the Club from the Association of Engineering Societies, the reduction of the amount of the annual dues, and changing the hour of meeting. These questions were discussed at some length, and to indicate the preference of those present, a vote was taken, resulting as follows: Continue membership in the Association, yes, 4; no, 14. Reduce annual dues, yes, 14; no, 4. Change meeting hour, yes, 8; no, 8.

It was finally decided proper to submit these matters to a vote of the entire membership, amendments to the By-laws being involved, which the Secretary was directed to do, with a circular explanatory of the situation, embodying in it the result of the vote above noted, the amount of the dues and the hour of meeting recommended being those in vogue before the changes made at the annual meeting in December, 1898.

The question of instituting a "Junior" class of membership, which was also suggested at the Executive Board meeting, was taken up and discussed,

Mr. Bogen presenting the following: "Amendment to the Constitution is proposed, as follows: That the grade of 'Junior' member be established and that the dues be one-half that for full membership."

As amendments to the Constitution can only be made at an annual meeting, the matter is in order for the December meeting.

The paper for the evening was read by Mr. James A. Lilly. It had been announced under the title of "Paint and Painting," but as an introduction, Mr. Lilly stated that in its preparation he had found the paper grow to such an extent that he had concluded to divide the subject and confine himself to the first word of the title—"Paint."

This he did in a very exhaustive and entertaining manner, going thoroughly into the merits of paints of various kinds, and the analysis and composition of the component parts of paints, pigments, oils, etc., and their manufacture.

After a discussion of the subject, participated in by Messrs. Gordon, Bogen, Morris, Jewett, Wulff, Warrington, Lilly and others, and a vote of thanks to Mr. Lilly, the meeting adjourned.

J. F. Wilson, *Secretary.*

14th Annual Meeting, Cincinnati, Ohio, December 19, 1901.—Dinner was served at 6.30 p.m. The regular meeting was called to order at 8.10 p.m., with President Jewett in the chair and seventeen members present.

Minutes of the meeting of November 21 were read and approved.

On motion the Chair appointed Messrs. Miller and Warrington a committee to canvass the votes received on the matters presented at the November meeting, and which had been submitted to letter ballot. The committee reported the result of the ballot, as follows: Continue membership in the Association of Engineering Societies, yes, 11; no, 24; total 35. Amend By-laws to provide for reducing amount of annual dues, yes, 26; no, 7; nil, 2; total, 35. Amend By-laws to provide for changing hour of meeting, yes, 17; no, 14; nil, 4; total, 35. Not counted, 3 votes unsigned. Upon which it was announced that it had been elected that the Club withdraw from the Association of Engineering Societies; that the annual dues and the time of meeting be restored to those prevailing before the change made at the annual meeting on December 15, 1898.

The question of proper amendments to the Constitution and By-laws to cover the proposed creation of a "junior" class of membership, presented at the November meeting, and also the changes as to annual dues and time of meeting, was discussed at some length, resulting in the appointment of Messrs. Bogen and Nicholson as a committee to prepare the same.

A proper resolution embodying the necessary amendments was submitted by the committee and adopted.

On motion to that effect it was resolved that the old custom of providing a light lunch after the meeting be observed in the future.

The Secretary and Treasurer presented his reports for the year 1901, which were accepted and ordered printed for distribution to the members. The report of the Secretary shows a reduction in average attendance from 16.3 in 1900 to 14.6 in 1901, the addition of five new members during the year, and a decrease in membership of 1 by death, 7 by resignations and 2 members dropped for non-payment of dues, leaving the total membership at the end of the year 82 as against 92 at the end of the previous year.

The Treasurer's report shows receipts of $605 and disbursements of $621.48, and a balance of $327.12 at the end of the year.

Officers for the year 1902 were elected as follows:

President—Louis E. Bogen.

Vice-President—A. O. Elzner.

Directors—H. E. Warrington, C. H. Meeds, Jas. A. Lilly.

Secretary and Treasurer—J. F. Wilson.

The retiring President, Mr. Wm. C. Jewett, read an address, taking for his topic a discussion of the affairs of the Club.

Address of Retiring President.

Gentlemen, of the Engineers' Club of Cincinnati,—First let us congratulate ourselves upon the selection of our President for the coming year. The choice is a wise one, and he will no doubt be the means of putting new life into the Club. an element of which we are sadly in need.

It has often occurred to us during the year that our members were losing interest in the Club, and in our discouragement we have examined the Secretary's reports, and to our pleasure find that our attendance is really above the average. It is true that we have lost in membership, but the proportion of actual members who have attended the meetings during the year has equaled that of similar societies. This proves that those who have remained with us have retained their interest in the welfare of the Club, and have performed their share of the work necessary to keep the Society alive.

The close of the year 1895 gave us the largest membership. The average attendance for that year was 20 per cent. of the members. Last year, with a membership of eighty-eight, we had an attendance of 19 per cent., from which it may readily be seen that the interest is maintained. The attendance of the November and December meetings show such an increase in the number present and such an activity among the members that it gives us every reason to believe we are to have a real revival. Let us continue this good work and see if we cannot have, not only a technical club, but a scientific one of value to the profession.

Section 2, Article II, of the Constitution, says that "an active member shall be a civil, military, mining, mechanical, electrical or hydraulic engineer." This covers the entire profession of engineering, making all engineers eligible to membership.

Let us glance at our list of members and see of what our society is composed. We have civil engineers, 59; mining engineers, 1; mechanical engineers, 10; electrical engineers, 3; architects, 1; associate members, 10. A total membership of 84. The civil engineers are largely in the majority, but we consider the number entirely too small when we see how many are engaged in the profession in this city, and how many young men should be associated with us who have taken up engineering as a profession. The small number of mining engineers is easily accounted for, as this is an agricultural region only. But in our midst are many factories, and these must employ many mechanical engineers and we certainly should have more than ten in our list of members. In fact I do not hesitate to say that our Club should have equally as many mechanical as civil engineers. In a city of this size we certainly should have a better representation in our Club of electrical engineers. Those we have are very active and interesting members, and a larger number would benefit all of us. We have but one architect with us, and he is one of our most active members. Now if he could only persuade a

few of his brethren to join us, we would have some valuable material added to our Society. The modern building requires not only the services of the architect, but those of the civil engineer as well. They are often interested in the same work, and if they were associated in the same technical society an interchange of ideas would be of benefit to both.

Our associate members have in many cases been active and regular attendants of the meetings. Would it not be well to bring more of them into our Society?

There is little doubt but that the creation of the "junior" grade in the Club will result in great benefit, not only to the juniors themselves, but to the Society at large. There are many young engineers and draftsmen that would unite with the Society in the proposed new grade that would not and could not enter as full members. This may be the means of adding many of the young engineering students from the university. They would be interested, add new life to the Society, and undoubtedly derive much information from the discussions of the older and practicing engineers.

Let us see if we cannot induce the coming engineers to spend a few evenings with us each year, for it will be only a short time until they will fill our places.

There appears to be a great dearth of papers in the Club, and when we note the number that have been furnished by friends during the past two years, it would seem that our Club is not capable of producing ten papers per year. But this is not true; a glance at the list of members tells us that there is not one who could not only write and read an interesting paper, but he could at the same time impart valuable information on the subject that is his especial work. Each engineer has his particular work, which differs materially from that of any other engineer. On this he devotes his entire time, thinking and investigating, spending many hours reading and studying, until he gathers ideas of other engineers; out of this mass of information he evolves new ideas and methods to suit his individual work. Now if the result of his labors was written in a short paper, and presented to the Club, there would be a record of his work which might otherwise be lost. Let as many members as possible prepare a paper this year, no matter how short. If we have more than can be read this year, we can have them next. Our custom has been to write long papers. During our present prosperous times, we are all so busy that few can devote the time necessary to write a formal paper that would require three-quarters of an hour to read. But most of us can write a five-minute paper, which would prove very interesting; and instead of one long paper two or three short ones could be read. Very often the shortest paper promotes the longest discussion. Let each member assume that he has a duty to perform, and if he performs that duty our Club will grow and flourish. We become interested in that for which we work. In these short papers we would learn much of each other's methods.

Our mechanical and electrical members could each tell us of some machine he had designed or constructed. The latter have given us some very interesting and instructive papers during the year, which we all appreciate. Each engineer could tell us of some structure he had built. He often spends weeks upon the design of a structure; while so doing has carefully studied into the methods of others and entirely new thoughts have occurred to him that would be most interesting to his brother engineers.

In choosing subjects let us not fail to consider the simple ones. They are the ones which often trouble us the most. Take what appears to be a very simple subject,—the mixing of concrete.

An entire evening could be spent upon the discussion of this subject with profit to all. There are many ways of doing this and each engineer has his own method and his reasons for considering his method the best. Unequal foundations for large structures. Every engineer has had this problem to solve, and he has in many cases found it a very difficult one. Having solved his problem satisfactorily, he has built his structure, which has settled equally, as all structures should, without cracking. He congratulates himself upon his success. Why should he not tell us how this was done and describe the method of preparing the foundation, that other members may profit by his experience? While on this subject, let us say to the members present that it is of the utmost importance that an engineer give his personal attention to the preparing of the foundations for important structures and that they should use every precaution for its stability. If this were done, we would have fewer failures of structures, accounts of which we read every week in our technical journals. Important matters of this kind cannot be left to the younger engineer, as he lacks the necessary experience which he must acquire with age. As an example, one structure that failed from lack of proper attention by the engineer in charge; although he may have used his best judgment, he failed in making a thorough examination. This was the pivot pier of a bridge in a small river. The pier was sunk to within three or four feet of rock, where it was stopped, resting on a bed of gravel. The pier, acting as an obstruction, caused the current to undermine the foundation, resulting in the pier settling on one side and standing at such an angle that it was necessary to take down the entire structure and reconstruct it on a rock foundation, as should have been done at first.

Earth dams; how should they be constructed? This is becoming a very important subject in this country, and up to a reasonable height this method of impounding water is largely used on account of the small cost. Nearly every engineer of experience has built earth dams, each using slightly different methods. Why not have a short paper on the subject and a lengthy discussion? It is true we can find numerous professional papers on earth dams, but at the same time a discussion may bring out thoughts that cannot be found elsewhere.

The best method of laying sewer pipe and inspection of the same. This is apparently a very simple problem, but to have sewer pipe properly laid is one of the most difficult tasks that an engineer has to perform, and the back filling of the trench takes all of his patience; and then very often after the first rain he will see the surface settle. This requires the very best inspection and supervision, and even then there is a constant fight to secure perfect results.

How to run a straight line. Every engineer has had this problem to solve, and all of us could profit by the experience of others. Easy? Not so easy either, rich in thought and one of the most difficult problems in railway location. Many a man has spent the evening and night studying how to hit a point five miles off, and after he has hit the point he has the problem of finding out if the line is a straight one. Usually it is not, and he must work on it until he has the proof that it is straight. The long tangents of many of the older railways are full of kinks, generally one at every summit and sag. This may be seen on many of the older railways in northern

Ohio. Engineers now spend more time on their tangents, and I believe usually have them reasonably straight.

Only a few of the subjects with which we are all so familiar have been mentioned to present to you; how simple a matter it would be for us to make our Club a most interesting one, if each of us would contribute a short paper during the year. Many societies require that a paper must be prepared and read by each member in his turn.

Most Clubs prepare a program at the beginning of each year, a committee being appointed to attend to the preparation. This is published in the annual volume. In this way the subject of each meeting is known far in advance. There is no doubt that this knowledge of the subject gives the members time to gather their information and come prepared for spirited discussions. I have in mind a woman's club of only twenty members that meets monthly. Their program is made up at the beginning of each year; it is an elaborate one and is carried out to the letter at each meeting, with a majority of the members present, all of whom take an active part in the literary discussions. I would suggest that the preparation of a program in advance, by a committee, be given a trial in this Club. The committee could communicate with the members who are willing to contribute papers, and the subjects could be published in the annual report and list of members.

Since we have decided to withdraw from the Association of Engineering Societies, it might be suggested that to take the place of that publication in our Society that we publish an annual volume, in which should be given a list of members, annual report, proceedings of the meetings and such papers as the members may furnish for publication. With a reduction of the dues this may not be possible, but we might consider the matter and meet the cost by other means.

We have a small library which in its present inaccessible condition is of little value to the members. A bookcase at a cost of thirty dollars and a few dollars each year for binding of periodicals would place the books where they would benefit the members. Some member who is interested in such matters might be persuaded to classify and index the library. A system of putting the books in circulation among the members should be devised and a librarian appointed to look after this particular work. The Secretary already has his hands full and should not be expected to take charge of the library.

An excellent feature of many technical societies is that of visiting, in a body, shops and public works under construction. Many Saturday afternoons could be profitably spent in this manner, and would result in greater sociability among the members. If it became known that our Club was in the habit of making these visits, many large shops and factories would possibly extend invitations to us. In fact many of our members are connected with these plants and would no doubt take pleasure in showing us through their works.

We may read of the methods used in the manufacture of a twelve-inch pipe, but we may never thoroughly understand the process and comprehend the details until we see the work actually performed. This may be said of nearly every piece of work. We have here one of the largest pipe foundries in the country, which might be visited with profit. There are large electrical plants and factories for the manufacture of electrical machinery, extensive machine shops; in fact nearly all branches of manufacturing are largely represented in Cincinnati.

One of our mechanical members has a model shop in the west end, for the manufacture of machine tools, that might be visited with profit to all. We have large railway plants, and extensive municipal improvements are under construction, all of which would be of interest, no doubt, to the members.

The time has now come for me to resign the chair to my successor. My great desire is to see him in every way successful, and that the Club may thrive under him as it has never done before.

Gentlemen, I thank you for your assistance during the year and your kind attention this evening.

J. F. WILSON, *Secretary.*

Boston Society of Civil Engineers.

BOSTON, MASS., NOVEMBER 20, 1901.—A regular meeting of the Boston Society of Civil Engineers was held in the Society's library at 8 o'clock P.M.; 8 o'clock P.M.; President L. B. Bidwell in the chair; forty-five members and visitors present.

The record of the last meeting was read and approved.

Mr. Leonard P. Wood was elected a member of the Society.

Mr. George T. Sampson read the paper of the evening, entitled "Railroad Organization," illustrating it with a number of lantern slides.

The discussion, which followed the paper, was participated in by Mr. James H. French, late superintendent of the Plymouth Division of the N. Y., N. H. and H. R. R., and by Messrs. C. F. Allen and J. P. Snow.

Adjourned.

S. E. TINKHAM, *Secretary.*

BOSTON, MASS., DECEMBER 11, 1901.—A special meeting of the Boston Society of Civil Engineers was held in the Society's library at 8 o'clock P.M.; Vice-President F. W. Hodgdon in the chair; eighteen members and visitors present.

Prof. L. J. Johnson read the paper of the evening, entitled "The Determination of Unit Stresses in the General Case of Flexure."

Adjourned.

S. E. TINKHAM, *Secretary.*

BOSTON, MASS., DECEMBER 18, 1901.—A regular meeting of the Boston Society of Civil Engineers was held at Chipman Hall, Tremont Temple, at 7.50 P.M.; President L. B. Bidwell in the chair. Fifty-six members and visitors present.

The records of the last regular meeting and of the special meeting of December 11 were read and approved.

Messrs. Langdon Pearse and James W. Tower were elected members of the Society.

On motion of Mr. Burke, the thanks of the Society were voted to the National Construction Company for courtesies extended this afternoon on the occasion of the trip to the tunnels of the Metropolitan Sewerage Works at Jamaica Plain; also to the Buff & Buff Manufacturing Company for courtesies extended during the inspection of its new shops at Jamaica Plain this afternoon.

The paper of the evening was presented by Mr. Frank W. Hodgdon, entitled "Notes in Relation to Docks and other Engineering Structures in Great Britain, France and Belgium."

The paper was very fully illustrated by lantern slides.

Adjourned.

S. E. TINKHAM, *Secretary.*

Technical Society of the Pacific Coast.

REGULAR MEETING, DECEMBER 6, 1901.—Held in the meeting hall of the Mechanics' Institute, 31 Post Street, for the first time. Called to order at 8.30 P.M. by Past-President George W. Dickie.

The minutes of the last regular meeting were read and approved.

The following propositions for membership were read and referred to the directors for regular ballot:

For members—Geo. H. Wallis, mechanical engineer, proposed by C. E. Grunsky, Luther Wagoner and Otto von Geldern; Geo. F. Day, mechanical engineer, proposed by Luther Wagoner, Adolf Lietz and Otto von Geldern.

Mr. Alpheus Bull, of San Francisco, was reinstated to membership from January 1, 1902, upon recommendation of the Board of Directors.

A communication was read from the Trustees of the Mechanics' Institute, indicating to the Society that the proposition of an affiliation as outlined in the agreement had been accepted, and that the Society is welcomed to the Institute as a member thereof. It is proposed by the Institute to hold a reception, to be given for the purpose of bringing together the members of the various affiliated societies, and those of the Mechanics' Institute, on Thursday evening, December 12, 1901, at the Library Building.

All members of the Technical Society of the Pacific Coast, the California Association, No. 3, National Association of Stationary Engineers and the Pacific Philatelic Society will be invited by individual cards.

Mr. Marsden Manson then read a paper entitled "The Distribution of Rainfall on the West Coasts of North and South America." The paper was illustrated by an elaborate map, showing the relative areas of precipitation in California, and the comparative distribution of forest growth.

The paper, containing some valuable records, was discussed at length by Past-President Grunsky.

In accordance with the Constitution and By-Laws, a Nominating Committee was appointed by selection of the members present, and duly confirmed by the casting vote of the Secretary, consisting of C. E. Grunsky, A. d'Erlach, James D. Mortimer, Hermann Barth and Hubert Vischer.

This committee is to select a ticket of officers for the ensuing year, and will meet for discussion of the subject on Monday, December 9, in the business office of the Society, 31 Post Street.

Mr. Frederick J. Toggart, Librarian of the Mechanics' Institute, appeared before the Society, and welcomed its members in the name of the library. He stated that it is his aim to create a first-class technical library, and that if members would indicate to him the names of desirable technical books and current engineering literature, every effort would be made on his part to obtain them, in order to make the library one of value and utility to the technical professions. He realized that this lack of technical literature had been long felt in San Francisco, and that the Institute will overcome the difficulty, and, in time, create a Mechanics' Library in the true sense of the word.

The meeting adjourned.

OTTO VON GELDERN, *Secretary.*

Engineers' Club of St. Louis.

534TH MEETING, DECEMBER 4, 1901.—Held at the Mercantile Club at 8.30 P.M.; Vice-President Kinealy presiding. Attendance, thirty-one members. Minutes of the 533d meeting were read and approved. Minutes of the 317th meeting of the Executive Committee were read.

The application for membership of Thomas K. Peters was read and referred to the Executive Committee. On ballot Mr. Fritz Lubberger was elected to membership.

Mr. Layman brought up for further discussion the propositions on which the members of the Board of Managers were requested to vote, regarding the Secretary's salary, indexing the JOURNAL, etc. There was some discussion.

A letter was read from the St. Louis Railway Club, inviting the members of the Engineers' Club to attend, on Friday, December 13, 1901, at the Southern Hotel, both their afternoon meeting and annual Christmas tree smoker, which is to be held in the evening. Motion was made and carried to tender a vote of thanks to the Railway Club and accept the invitation.

The next order of business was the reading of the annual reports of the officers and various committees of the Club. Owing to the absence of the President, no report of the Executive Committee was made. The Secretary's report was read and on motion made and carried it was accepted and filed. The Treasurer's report was read and referred to the Executive Committee. Reports of the Librarian, members of the Board of Managers, and Entertainment Committee were read and motion was carried that they be accepted and filed. The report of the Committee on Prizes was read. The Chair announced that the recommendations of the committee had been approved by the Executive Committee at their meeting of November 6, and in accordance with their recommendations he was pleased to award the prize to Mr. J. S. Branne for his paper, entitled "The Steel Skeleton Construction of a Tall Office Building," which was read before the Club at the meeting held November 7, 1900.

The Nominating Committee made its report on nominations for officers for the ensuing year, as follows:

For President—J. M. Kinealy, F. B. Maltby.

For Vice-President—E. A. Hermann, J. L. Van Ornum.

For Secretary—D. W. Roper, A. H. Zeller.

For Treasurer—Geo. I. Bouton, N. W. Perkins, Jr.

For Librarian—E. B. Fay, W. H. Henby.

For Directors—Carl Gayler, A. L. Johnson, E. J. Spencer, Wm. Wise.

For Members Board of Managers of Engineering Societies—E. R. Fish, J. A. Laird, W. A. Layman, P. N. Moore.

Additional nominations were made as follows:

For President—E. A. Hermann.

For Vice-President—A. H. Blaisdell.

For Secretary—W. H. Bryan.

For Librarian—Walter Brown.

For Directors—W. A. Layman, H. L. Reber.

For Members Board of Managers—E. E. Wall, E. B. Fay.

Motion was made and carried that an annual banquet be held on Wednesday evening, December 18, 1901, the price per plate not to exceed $3.50. The Executive Committee was authorized to make the necessary arrangements.

The meeting then adjourned and members remained seated while a lunch, provided by the Entertainment Committee, was served, during which every member present was required to make a speech or tell a story. A very enjoyable evening was spent.

E. B. Fay, *Secretary pro tem.*

535th Meeting, December 18, 1901.—The annual dinner of the Club was held at the Mercantile Club at 8 p.m.; President Spencer presiding. There were thirty-seven members and five guests present.

After dinner had been served the Club was called to order and announcement made of the Executive Committee's report of the letter ballot for officers for the ensuing year, with the following result:

For President—J. H. Kinealy was elected.

For Treasurer—Geo. I. Bouton was elected.

For Librarian—Edw. B. Fay was elected.

For Member Board of Managers—F. R. Fish was elected.

For Vice-President, Secretary, two Directors and one member of Board of Managers there was no election, none of the candidates having received a majority of the votes cast.

As the newly-elected President, Mr. Kinealy, was not present Mr. Spencer retained the chair and ruled it in order to fill the above-mentioned vacancies.

After the ballots were taken the following results were announced, viz:

Vice-President—J. L. Van Ornum.

Secretary—D. W. Roper.

Directors—A. L. Johnson and E. J. Spencer.

Member Board of Managers—J. A. Laird.

The first toast on the program was "Remarks by the Retiring President," in which Mr. Spencer gave a short talk appropriate to the occasion and thanked the Club for the cordial support given him during the past year.

Mr. S. Bent Russell then responded with an interesting address on "When is Engineering Profitable as an Investment?"

Col. E. D. Meier, one of the Club's oldest members, then gave an interesting talk in which he discussed the spirit of "Commercialism" of the present age, and predicted that the present century would be one of "engineering" in which the work of the engineer would predominate. The subject assigned to him was Helios, "The Sun do Move."

The next subject on the program was "International Expositions and Engineering Practice," by Henry Rustin, electrical engineer of the Louisiana Purchase Exposition. Mr. Rustin, however, was absent, and Dr. David Day, chief of the Department of Mines and Metallurgy, Louisiana Purchase Exposition, kindly responded with a very entertaining and instructive talk on the work already done and that which his department expected to do toward making the exposition a great success. He urged all to give their hearty support to the project.

Mr. J. A. Laird followed by responding to the toast, "Community of Interests Among Engineers," in which he urged a thorough organization of engineers.

The Chair then called upon Mr. Philip N. Moore, who responded in a very happy vein in behalf of the many disappointed candidates.

Adjourned.

W. G. Brenneke, *Secretary.*

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JOHN C. TRAUTWINE, Jr., Secretary,
257 SOUTH FOURTH STREET,
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